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RELATIONSHIP BETWEEN THE 20 METER SHUTTLE RUN TEST AND SELECTED OCCUPATIONALLY-RELATED ARMY FIELD TASKS

by

RANDY WILLIAM DREGER

A Thesis submitted to the Faculty of Graduate Studies and Research in partial fulfilment of the requirements for the degree of Master of Science

Faculty of Physical Education and Recreation

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research, for acceptance, a thesis entitled **RELATIONSHIP BETWEEN THE 20 METER SHUTTLE RUN TEST AND SELECTED OCCUPATIONALLY-RELATED ARMY FIELD TASKS** submitted by **RANDY WILLIAM DREGER** in partial fulfilment of the requirements for the degree of **MASTERS OF SCIENCE**.

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Dr. Dan Syrotuik

Dr. Dru Marshall

Dr. David Reid

Date..April 14.....1998

DEDICATION

This manuscript is dedicated to those who have seen me through my post-secondary education. I would like to thank my parents, Raymond and Dale Dreger, who have supported my endeavour in countless ways. Their example of dedication and hard work provided the foundation for me to meet the challenges of life. Words cannot express my thanks to you.

To my loving wife, Holly, your support and sacrifice have been greater than you may think. It was your support and understanding that allowed me to fulfil my dreams. Although this work is a permanent record of my masters, it is but a glimpse of what I have gained. I hope that now you too may enjoy such an opportunity.

ABSTRACT

The purpose of this study was to examine the relationship between the 20 Meter Shuttle Run (20MSR), Indoor Standardized Obstacle Course (ISOC), and slit-trench digging task.

Seventy-five male Canadian soldiers (age 26.69 ± 4.53 years; height 178.27 ± 6.88 cm; weight 83.52 ± 13.10 kg; body fat 25.3 ± 4.76%) participated in this study. Following a familiarization session, each subject performed all the tests over a two day period.

Mean VO_2 max values were 41.66 ± 5.12 ml · kg^{-1} · min^{-1} or 3.44 ± 0.05 L · min^{-1}. Mean slit-trench digging and ISOC performance times were 4:19 ± 0:46 min:sec and 5:19 ± 0:38 min:sec, respectively. A significant ($p<0.05$) relationship between ISOC performance and relative VO_2 max ($r = -.64$) and between slit-trench digging performance and absolute VO_2 max ($r = -0.28$) was found. Linear regression indicated that 42% of ISOC performance and 8% of trench digging performance was accounted for by the 20MSR.

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CHAPTER I

STATEMENT OF THE PROBLEM

A. INTRODUCTION

A high level of physical fitness is an important requirement for military personnel, despite the continued mechanization and automation of warfare. Modernization of the Canadian Forces (CF) has prompted the use of military vehicles to transport guns, ammunition, and other supplies that infantry personnel traditionally carried. In addition, today's soldier, instead of marching, is often transported in armoured personnel carriers or helicopters. However, modernization does not always reduce the physical demands placed on a soldier. The Falkland experience required soldiers to march distances as far as 60 km while carrying loads as heavy as 60 kg (Lee et al., 1991).

The Gulf War provides another example of some of the demands a modern soldier may face. During the Gulf War, soldiers frequently had to perform their duties in hot, heavy, protective clothing due to the threat of chemical or biological attacks; in addition, thermal stresses were compounded by daytime temperatures of up to 37°C. Specialized equipment, such as night vision goggles and infrared guided missiles, made the 24 hour battle-day a reality, forcing soldiers to fight for extended periods without adequate rest or sleep. The combined effect of these factors greatly increased the physical demands of many routine tasks.

The Combat Arms division, which is composed of infantry, artillery, armour, and combat support personnel, is a branch of the army that performs physically demanding tasks

as part of their daily operations. To perform their job safely and proficiently, combat arms personnel must possess above average levels of aerobic power and capacity, anaerobic power and capacity, muscular strength, muscular endurance, and flexibility (Singh et al., 1991). Aerobic fitness is one component that is essential for the performance of many traditional army activities such as trench digging, navigating obstacles, weight load marching, patrolling, loading and unloading ammunition boxes, as well as non-traditional army activities such as firefighting and flood control (Lee et al., 1991). The aerobic fitness level of a soldier is even more important when these activities are performed in severe environmental conditions like those encountered in the Gulf War.

Over the past few years, the CF, due to government cutbacks and reorganization, has reduced the number of active military personnel. With a limited number of personnel, a greater demand is placed upon each individual soldier and reservist. Research has indicated that even though soldiers may train regularly and vigorously, their aerobic fitness may decline to unsatisfactory levels (Gordon et al., 1986). This may also be true for some reservists, especially those who lead relatively sedentary lifestyles when away from their military duties. Since a soldier may be called into battle at any time, they must always be physically prepared for combat. To ensure a soldier is physically fit for combat duties, the CF has implemented and used a variety of fitness tests. Aerobic fitness is one component commonly assessed by the CF to determine a soldier's preparedness for combat.

To assess aerobic fitness, military institutions from around the world have utilized an array of tests such as the two mile run/walk test (Vogel, 1994), the 12 minute Cooper run (1968), the Basic Fitness Test (Vogel, 1994), as well as occupationally-related activities such

as weight load marching and obstacle course performance (Kimick, 1987). Maximal oxygen uptake (VO_2 max) is an aspect of aerobic fitness often measured. As Fitness Canada (1987) has stated, VO_2 max is the criterion measure for aerobic fitness.

Since 1983, the CF has used the Canadian Aerobic Test of Fitness (CAFT), a double step test, to determine the aerobic fitness of CF personnel (CF EXPRES, 1989). Although an appropriate means of gross fitness evaluation, the CAFT may not be sensitive enough to detect minor but significant changes in aerobic fitness (Lee et al., 1992). In addition, the CAFT tends to overestimate the VO_2 max level of unfit soldiers and underestimate the VO_2 max level of fit soldiers (Fitness Canada, 1987). As part of a study to develop physical fitness standards for CF personnel, Stevenson et al. (1992) did not find a significant relationship between VO_2 max values, as predicted by the CAFT protocol, and selected military activities, which calls into question the validity of the CAFT as a reliable measure of military fitness.

In light of the problems associated with the CAFT, the CF has started to examine the 20 meter shuttle run test (20MSR) to assess the aerobic fitness of its personnel. Developed by Leger and Gadoury (1989), the 20MSR involves running/jogging back and forth in a straight line from one point to another 20 m apart, in time with a prerecorded audio tape. As the test progresses, the frequency of beeps increases. The test is terminated when the soldier is unable to maintain the pace set by the audio tape. Using the final stage attained, a soldier's relative VO_2 max is determined.

The 20MSR has been determined to be valid and a reliable predictor of VO_2 max (Leger and Gadoury, 1989) that can be easily administered to a large group of soldiers within a small gym space and that involves minimal equipment and training, thus making the

20MSR an ideal testing protocol for the military.

In 1978, the Canadian Parliament implemented bona fide occupational guidelines as part of the Canadian Human Rights Act. In regard to physical fitness, bona fide occupational guidelines require a test to demonstrate a relationship between performance and the physical demands of an occupation (Canadian Human Rights Act, 1985). Many institutions are using occupationally-related tests, as opposed to general fitness tests, because of their ability to demonstrate face validity in a court of law. Judges perceive occupationally-related tests to be appropriate because they simulate or replicate the actual job tasks (Shephard, 1990). Legislation has prompted a move away from general tests of fitness such as situps, pushups, and the step test, as these general tests are believed to have little or no validity in assessing the ability to perform occupational tasks.

In some situations, occupationally-related fitness tests do not provide essential information about specific physiological parameters, in which case it is justifiable to use general fitness tests instead. Conversely, as part of the validation of bona fide occupational guidelines, occupationally-related tests may be used to validate the use of general fitness tests (Shephard, 1991).

Singh et al. (1991) and Jette et al. (1990a) developed two occupationally-related fitness tests for the CF: slit-trench digging and the Indoor Standardized Obstacle Course (ISOC). In slit-trench digging, a soldier digs a hole with dimensions approximately two meters in length, half a meter in width, and about half a meter deep, commonly referred to as a fox hole. Digging a slit-trench is a basic military task that every soldier is expected to be capable of performing. The slit-trench provides protection from incoming enemy fire and

establishes a defensive position from which to attack safely (Singh et al., 1995). Under certain battle conditions, the physical ability to quickly dig a slit-trench may be crucial to survival. Maximal oxygen uptake is one physiological component significantly related to slit-trench digging performance (Singh et al., 1995), which lends support to the idea that soldiers require a specific minimal level of VO_2 max for optimal trench digging performance.

A familiar sight at most CF bases is an obstacle course. For years, military institutions have used obstacle courses to train and evaluate the physical condition of their soldiers (Pratt, 1987). However, many obstacle courses are outdoors or require special equipment not commonly found on a military base. These factors make it difficult to construct and standardize traditional obstacle courses. In the mid 1980's, Kimick and associates developed an indoor obstacle course using materials traditionally found at a military base. In addition, they standardized the dimensions, weights, and sequence of the obstacles; they referred to their format as the Indoor Standardized Obstacle Course (ISOC). The purpose of the ISOC was to evaluate the occupationally-related physical fitness of CF soldiers. The ISOC consists of common military activities, such as crawling, scaling walls, loading ammunition boxes, carrying sandbags, and overhead traversing, which are performed in a specific order, as quickly as possible. A significant relationship has been found between ISOC performances and many physiological parameters. Jette et al. (1990a) demonstrated that direct measure of VO_2 max was significantly related to ISOC performance.

The 20MSR is currently being examined by the Directorate of Physical Education, Recreation and Amenities, in terms of its practicality and its relation to military occupational activities. In order for the 20MSR to meet the bona fide occupational guidelines, it is

necessary to demonstrate a high test/retest coefficient of reliability, construct and content validity, and a demonstrated relationship to occupationally-related tasks (Shephard, 1990). Previous research has demonstrated that aerobic fitness (VO_2 max) is an essential physical fitness component for military duty (Vogel, 1994). The 20MSR is highly related (r=0.95) to direct measures of VO_2 max (Leger et al., 1988). Slit-trench digging and ISOC performances are significantly related to directly measured VO_2 max values (Singh et al., 1991; Jette et al., 1990a). It would be logical to postulate a relationship between the 20MSR, trench digging, and the ISOC. However, before accepting the 20MSR as a measurement of aerobic fitness in the military setting, one condition must be met. It must be scientifically demonstrated that the 20MSR has a proven relationship to occupationally-related military tasks.

B. PURPOSE OF THE STUDY

The purpose of this investigation was to determine the relationship between the 20MSR and occupationally-related military tasks (slit-trench digging and the Indoor Standardized Obstacle Course).

C. SIGNIFICANCE OF THE STUDY

The significance of this study is that it provides the CF with information necessary to determine the 20MSR's appropriateness as a test of aerobic fitness in accordance with bona fide occupational guidelines. The CF requires an aerobic fitness test that is valid, objective, cost effective, and easy to administer. The 20MSR meets the aforementioned criteria; however, before the CF adopts the 20MSR, a reliable relationship between the

20MSR and occupationally-related military tasks must be demonstrated. If the results of the present investigation show a relationship between VO_2 max, predicted by the 20MSR and occupationally related military tasks that is dissimilar to the previously established relationship between direct measures of VO_2 max and occupationally related military tasks, a different test of aerobic fitness will have to be found.

D. NULL HYPOTHESIS

The following null hypothesis was tested in this study ($p<0.05$).

The 20MSR and two occupationally-related military tasks (slit-trench digging and Indoor Standardized Obstacle Course) will not be significantly related.

E. LIMITATIONS OF THE STUDY

1. This study was part of a larger investigation. Therefore, subjects and testing procedures were selected and administered in the context of the larger investigation.
2. Motivation of the participants could not be controlled. However, consistent verbal encouragement for maximal performance was given to each subject by the researchers during each testing session. In addition, all subjects received standardized test instructions to help ensure uniform participation.

F. DELIMITATIONS OF THE STUDY

1. This study was delimited to 75 healthy, as determined by a health

questionnaire, male Canadian soldiers.

2. Laboratory measures were delimited to the following test variables:

    I. 20 meter shuttle run test

    II. Body Composition:

        i. Height

        ii. Weight

        iii. Skinfold measures of the Triceps, Biceps, Subscapular, Iliac Crest, and Medial Calf

        iv. Percent body fat

        v. Body Mass Index (BMI)

3. Occupationally-related tests were delimited to the following:

    I. Slit-trench digging

    II. Indoor Standardized Obstacle Course (ISOC)

F. OPERATIONAL DEFINITION OF TERMS

1. **Maximal oxygen uptake (VO_2 max)**: Refers to the maximal volume of oxygen consumed per minute during a progressive cardio-respiratory exercise test.

2. **Aerobic power:** Used synonymously with maximal oxygen uptake.

3. **Laboratory-Like Tests**: Tests completed under controlled circumstances, using scientifically proven methods.

4. **Occupationally-Related Tests**: Tests that simulate specific activities encountered by individuals in a specific occupation. These tests are standardized and completed under controlled circumstances, using scientifically proven methods.

5. **Physical Training Order**: Includes combat pants, shirt, and boots.

6. **Full Fighting Order**: This dress order includes combat clothes, helmet, weapon and rucksack (backpack) with summer order (24.5 kg total weight).

CHAPTER II

REVIEW OF LITERATURE

A. INTRODUCTION

Numerous investigations have demonstrated that aerobic fitness is an important physiological component involved in the performance of several military activities (Daniels et al., 1984; Defence Research Group, 1986; Jette et al., 1989, 1990a; Kimick, 1987; Lee, 1992; Singh et al., 1991). Military activities that require a high level of aerobic fitness include weight load marching, trench digging, obstacle course navigation, and loading ammunition (Jette et al., 1989, 1990a; Vogel, 1994). To ensure that soldiers have the required aerobic fitness level to successfully perform military activities, several aerobic fitness tests have been developed and utilized by various military institutions, including the Canadian Forces (CF). Maximal oxygen consumption (VO_2 max) is a component often measured as an indicator of aerobic fitness. The most reliable and valid technique of determining VO_2 max is by direct measurement. However, direct measurements are costly, time consuming, and require special equipment and highly trained technicians. CF commanders, responsible for the military training and testing of their soldiers, prefer tests that are easily administered, valid, objective, and cost-effective (Myles et al., 1985).

Indirect VO_2 max tests are usually referred to as predictive tests. Several predictive VO_2 max tests measure workload and/or heart rate in order to calculate the estimated metabolic cost of work. The CF is in a transition phase, by replacing the Canadian Aerobic Fitness Test (CAFT) (Fitness Canada, 1987) with the 20 meter shuttle run tests (20MSR)

(Leger and Gadoury, 1989). The CAFT is a predictive test of VO_2 max that is time consuming, requires trained staff and special equipment. The 20MSR is a VO_2 max test that is easily administered, requires little specialized equipment or training, and can be performed in a gymnasium; the major advantage is that the 20MSR can test a large number of subjects simultaneously, making it suitable for testing in the military. However, while these factors may merit the inclusion of the 20MSR in a military testing battery, the 20MSR must still meet the requirements set forth by the Canadian Human Rights Commission (1985).

The Canadian Human Rights Act (1985) stated that occupationally-related fitness tests must demonstrate a scientifically proven relationship between test results and the physical demands of the job. The CF have responded to this legislation by developing occupationally-related fitness tests based upon rigorous scientific methods (Singh et al., 1991). Occupationally-related fitness tests developed by Singh et al. (1991) have made the CF a leader in this field. Currently, the CF is attempting to determine if the 20MSR meets legislative requirements. Before full implementation, the establishment of a reliable relationship between the 20MSR and occupationally-related military fitness tests is required (Stevenson et al., 1992).

Previous investigations have examined the relationship between direct measures of VO_2 max and occupationally-related fitness tests. Singh et al. (1991) and Jette et al. (1990a) reported that directly measured VO_2 max significantly correlated with slit-trench digging ($r=-0.48$) and Indoor Standardized Obstacle Course (ISOC) performance ($r=-0.73$). Therefore, to abide by the Canadian Human Rights Act, the CF must demonstrate that the 20MSR is significantly correlated with occupationally-related fitness tests.

B. AEROBIC DEMANDS OF MILITARY DUTY

Although the aerobic fitness level of a soldier has been emphasized by military units from around the world (Defence Research Group, 1986, 1994; Vogel, 1994; Jette et al., 1989), there is, however, little published research detailing the aerobic requirements of specific military activities. Much of the literature describes either the aerobic fitness level of military personnel at a particular point in time or the effects that a specific training program has on aerobic fitness.

Investigations conducted by the NATO Defence Research Group (DRG, 1986) demonstrated that a typical 16 km march in full fighting order, completed on flat even ground in less than two hours, required an energy expenditure of approximately 2.0 $l \cdot min^{-1}$ (28.6 $ml \cdot kg^{-1} \cdot min^{-1}$, for a 70 kg soldier). In addition, the DRG stated that if the terrain is hilly or uneven, energy demands may be increased by as much as twofold (4.0 $l \cdot min^{-1}$ or 57.2 $ml \cdot kg^{-1} \cdot min^{-1}$, for a 70 kg soldier). Similarly, heavier loads or extra protective clothing may also increase the aerobic energy requirements.

The DRG also reported that loading ammunition shells for a 155 mm Howitzer at a rate of one shell per minute required an energy expenditure of approximately 1.5 $l \cdot min^{-1}$ (21.4 $ml \cdot kg^{-1} \cdot min^{-1}$, for a 70 kg soldier). To avoid undue fatigue during a typical eight hour work day, of marching and shell lifting, a 70 kg soldier would require a VO_2 max of 43 to 50 $ml \cdot kg^{-1} \cdot min^{-1}$ or 3.0 to 3.5 $l \cdot min^{-1}$ (DRG, 1986).

In 1991, Singh et al. examined the physiological demands of five common military activities: trench digging, casualty evacuation, jerry can carrying, weight load marching, and ammunition box lifting. Singh et al. (1991) demonstrated that in order to perform the tasks

successfully, a soldier required a VO_2 max of 3.15 l • min^{-1} (45 ml • kg^{-1} • min^{-1} for a 70 kg soldier). Stevenson et al. (1992) performed an investigation similar to that of Singh et al. (1991), using a series of military activities including land evacuation, sea evacuation, trench digging, sandbag carry, and low/high crawl. Stevenson et al. (1992) reported 39 ml • kg^{-1} • min^{-1} was the minimum VO_2 max necessary for military personnel to perform these tasks effectively.

In addition to traditional military activities, a soldier may be required to respond to unique emergency situations such as riots, floods, and fires (Mayo, 1984). In order to perform these tasks, a soldier requires a specific level of physical fitness that meets the demands of these jobs. For example, Gledhill and Jamnik (1992) determined that a minimum VO_2 max value of 45 ml • kg^{-1} • min^{-1} was necessary to meet the aerobic demands of firefighting.

Although aerobic fitness is an important component for the performance of many military tasks, most of these tasks require more than one fitness component. However, with sufficient intensity and/or duration, the task may become more dependent upon aerobic metabolism. For example, a single lift of a 20.9 kg ammunition box is largely a function of the strength component. If the task was preformed repeatedly, it would require increased muscular endurance. If sufficiently prolonged, the aerobic component would come to play a dominant role (Vogel, 1994). If a task continues beyond a certain time without allowing for sufficient recovery, work output would decrease because of fatigue (Åstrand and Rodahl, 1986).

Glesser and Vogel (1973) demonstrated that a soldier could work at 50% of VO_2 max for up to eight hours. However, if a soldier worked at 50% of VO_2 max continuously eight

hours per day, five days per week, the physical demand may become too great, causing excessive fatigue; therefore, it is recommended that work rates for an eight-hour work day should vary between 35% to 50% of VO_2 max (Åstrand and Rodahl, 1986). If a task requires a work rate of 60% VO_2 max, it may be sustained for approximately two hours, whereas tasks that require work rates of 75% VO_2 max should not exceed approximately 30 min in duration (Vogel, 1980).

In many combat situations, a soldier's safety may be compromised if he or she does not possess adequate aerobic fitness. Under severe environmental conditions or during 24 hour battle conditions, a soldier may require a greater percentage of VO_2 max to perform occupationally-related tasks. In applying the inverse relationship between intensity and duration, Burkett et al. (1983) reported that, in order for a soldier to perform duties through five days of continuous close combat operations, a minimum VO_2 max of 45 ml • kg^{-1} • min^{-1} would be necessary.

The literature clearly demonstrates the importance of aerobic fitness for the performance of military duties, with VO_2 max values from 39 to 50 ml • kg^{-1} • min^{-1} being considered adequate; however, 45 ml • kg^{-1} • min^{-1} was most commonly cited as the necessary minimum to perform military duties.

C. TESTING AEROBIC FITNESS

Given that a soldier requires a VO_2 max of approximately 45 ml • kg^{-1} • min^{-1}, it is vital that military institutions have a means of determining whether a soldier has the aerobic fitness to perform combat and occupationally-related tasks. A common measure of aerobic

fitness is maximal oxygen consumption (VO_2 max). Maximal oxygen consumption has been defined as "that point during progressive exercise at which oxygen consumption ceases to rise and reaches a plateau or begins to fall although the work rate continues to increase" (Thoden, 1992, p. 130). In order to test VO_2 max, the following test criteria should be considered:

1. The activity should be continuous, progressive, and rhythmical in nature, utilizing large muscle groups.
2. The initial work rate should be of an intensity low enough to provide a proper warm up.
3. Intensity should be increased by approximately 1.5 - 2.0 ml • kg^{-1} • min^{-1} per incremental increase to avoid the early onset of fatigue due to anaerobic metabolism.
4. The subject should be brought to VO_2 max within 8 to 12 minutes.
5. The task should closely resemble the participant's principal activity or activities.
6. All participants should be able to perform the test with similar levels of mechanical efficiency.

(Thoden, 1992; Fitness Canada, 1987)

Using these criteria as a guideline, the optimal method of measuring VO_2 max is by collecting and analyzing the gases expired from a subject during uninterrupted uphill treadmill running (Thoden, 1992). In addition, running protocols usually produce higher maximal oxygen uptake values and reduce the risk of local muscular fatigue that occurs with

cycle ergometer protocols (Brooks et al., 1996; Thoden, 1992).

Another factor to consider when testing VO_2 max is lactate threshold (LT). Lactate threshold, anaerobic threshold, and onset of blood lactate accumulation are terms often used to describe an exponential increase in blood lactate concentration at a particular level of oxygen uptake. Similarly, ventilatory threshold has been used to describe the breaking point of pulmonary ventilation versus oxygen uptake (Åstrand and Rodahl, 1986). In order to measure LT and ventilatory threshold both specialized equipment and trained technicians are required. Either an analysis of a blood sample or respiratory exchange ratio are used to detect the LT and ventilatory threshold, respectively.

The relationship between LT and VO_2 max is usually described in terms of LT as a percentage of VO_2 max. For example, Denis et al. (1984) noted that, for well-trained competitive runners, LT occurred at an intensity approximately 83% of VO_2 max, while Hurley et al. (1984) reported LT occurrence at 68% of VO_2 max for sedentary individuals. Thoden (1992, p. 111) stated, "Normally, [individuals] who have a high VO_2 max also have a high LT, but the relative importance of both varies depending on the event [activity] or sport in which the [subject participates in]." Work intensities below LT (30 to 50% VO_2 max) may be performed for hours and are primarily limited by substrate availability. However, work rates above LT (~65 to 100% VO_2 max) may be performed for as little as six to eight minutes at an intensity equivalent to VO_2 max (Thoden, 1992). In events in which performance is near LT, such as marathon running, there is a greater relationship between successful performance and LT than between performance and VO_2 max. However, in activities with performance levels at or above VO_2 max, a higher maximal oxygen uptake

would be more beneficial to the subject than a high LT level (Thoden, 1992).

Although sophisticated laboratory measurements involving gas and blood analysis are precise at measuring aerobic fitness, the necessary equipment is often not available in military field-testing situations. Occasionally, laboratory measures are used by NATO countries for entrance testing or scientific study, but rarely are they used to evaluate the fitness of a troop of soldiers (Vogel, 1994). At present, there are no valid, reliable, easy to administer, and cost effective methods to directly determine LT and VO_2 max of CF soldiers on a large scale. Therefore, CF commanders are constrained to use predictive VO_2 max tests that meet the guidelines stated previously.

D. FITNESS TESTING IN THE MILITARY

Several military fitness tests are intended to evaluate the ability of a soldier to perform occupationally-related duties (Von Restorff, 1994). Training exercises and simulated combat manoeuvres are methods used to determine a platoon's ability to perform under combat conditions. These manoeuvres can often simulate a variety of battle situations and conditions, with tanks, armoured cars, and helicopters being utilized to perform specific strategies and tactics. Although combat manoeuvres provide one of the most specific forms of training and testing, the manoeuvres primarily evaluate the military fitness of soldiers at the platoon level rather than at the individual level. In addition, there is substantial financial cost associated with combat manoeuvres, thus limiting their use (Vogel, 1994). Clearly, there is a need for physical performance tests that are predictive of both physical capacity and military task performance, which can be carried out without large financial cost.

A common problem associated with many less expensive physical fitness testing procedures is their lack of ability to measure both physical capacity and task performance. For example, situp and chinup tests measure primarily upper body muscular endurance, where as the 12-min run/walk test primarily measures aerobic fitness. In addition, many of these single component physiological tests are poor predictors of military performance. For example, performance in the muscular endurance task of pushups has a low correlation with performance in lifting heavy artillery rounds. Similarly, the relationship between five kilometer run performance and weight load march performance is low (Vogel, 1994). In many cases, more than one physiological factor may influence the performance of occupationally-related military tasks (Von Restorff, 1994; Jette et al., 1989). Therefore, physical fitness tests must not only be able to evaluate specific fitness components, but must also show a relationship to performance of military activities.

In order for military commanders to evaluate the aerobic fitness of their troops, they have often used predictive tests of VO_2 max such as timed 1.5 or 2 mile runs (Vogel, 1994) and the 12 minute distance run (Cooper, 1968). The correlations between these predictive tests and direct measures of VO_2 max vary from fair to good, depending on testing conditions and the motivation of the subjects (Leger and Gadoury, 1989). Many of the predictive tests used by the military to determine aerobic fitness do not have built-in pacing system. Thus, novices to the tests may select a pace or intensity of exercise that may induce the early onset of anaerobic metabolism, resulting in fatigue (Thoden, 1991; Leger and Gadoury, 1989; Fitness Canada, 1987; Åstrand and Rodahl, 1986). In addition, timed runs do not have a built-in safety factor, making them potentially dangerous for some individuals

with heart conditions (Brooks et al., 1996). The following overview of fitness tests utilized by selected military institutions demonstrates the variety of military testing programs currently used.

United States Air Force

The United States Air Force uses a single physical fitness test for its soldiers. Annually, soldiers are tested for aerobic fitness using a submaximal cycle ergometer test. The passing standards for soldiers are found in Table 1 (Vogel, 1994).

Table 1.
VO_2 max ($ml \cdot kg^{-1} \cdot min^{-1}$) Standard for the United States Air Force

Age (years)	<30	30-39	40-49	> 49
Males	34-42	32-39	30-36	28-32
Females	27-36	26-34	26-31	23-26

United States Army

The United States Army Physical Fitness Test (APFT) is administered to all personnel twice a year. It consists of three tests: maximum number of pushups performed in two minutes, maximum number of situps performed in two minutes, and a timed two mile run. Results are age and gender adjusted to determine fitness levels (Vogel, 1994).

Portugal

The Portuguese use an annual 12-min run/walk test to estimate aerobic fitness. However, this test is not used to predict VO_2 max. Performance is based upon the distance covered in 12 min, which is graded on a scale from zero (unacceptable) to 20 (very good) (Vogel, 1994).

United Kingdom

There are two fitness tests for British soldiers: the Basic Fitness Test (BFT) and the Combat Fitness Test (CFT). All soldiers under the age of 40 are required to perform the BFT twice a year. As a test of aerobic fitness, the BFT is performed on level ground that offers a good running surface. The test consists of a 2.4 km (1.5 mile) squad run/walk in 15 minutes that is directly followed by a run of 2.4 km (1.5 miles) on which an individual's best effort is evaluated. Scores are graded based upon age and gender.

The CFT is performed in two parts. Part one includes a 12.8 km (8 mile) squad march which is to be completed in two hours or less. Soldiers wear full fighting order and carry, depending on their occupation, an additional 13-15.5 kg (30-35 lbs) of equipment. At least three of the eight miles must be off paved roads. Part two of the CFT consists of jumping a 1.5 m (5') ditch, mounting and dismounting a four-ton truck with tailboard up, and lifting and carrying a soldier of similar height and weight for 90 m (98 yard) using a Fireman's Carry (Vogel, 1994).

Germany

The German Federal Forces utilize the Military Competitive Test (MCT) to measure improvements due to training. In addition, it is administered annually to monitor the individual soldier's physical fitness level. The MCT consists of five major event categories (swimming, jumping, sprinting, putting, and distance running), with up to five individual events within each major category. Soldiers choose an individual event in which they wish to be tested. However, they must attempt at least one event in each category (Vogel, 1994).

Summary

The purpose of testing a soldier's physical fitness level is to determine his or her ability to perform military duties. Although training manoeuvres are the most specific method of evaluating combat performance, they are costly, elaborate, and time consuming. Less expensive and more easily administered tests are frequently used in place of training manoeuvres. A variety of techniques are used in the prediction of military performance and physical fitness, ranging from the norm referencing approach of the US army, Germany, and Portugal, to the laboratory method employed by the US air force, to the military-related approach of the United Kingdom. However, no clear consensus exists as to which method is superior for the prediction of both physical fitness and military performance.

E. FITNESS TESTING IN THE CANADIAN FORCES

An integral part of CF operations has been physical fitness testing of military personnel. In 1971, the CF implemented a battery of common tests that measured muscular strength and endurance, cardiovascular endurance, and agility. These fitness components were considered to be representative of the physical demands of CF duty, which needed to be maintained through regular physical training. However, much of the emphasis was placed on passing the test, with little consideration for the development or maintenance of physical fitness after testing. A number of commanders, believed that the tests were not related to military tasks and refused to participate in the program. In addition, CF commanders and administrators perceived that injuries incurred during the testing was a result of inadequate preparatory and poor screening programs. Therefore, the test battery was discontinued one

and a half years after implementation (Mayo, 1984; Lee, 1992).

In 1973, the CF moved to the 2.4 km (1.5 mile) run as the only means of assessing the physical fitness of its members. Test results were interpreted using age and gender standards based on the Åstrand nomogram (Åstrand and Rodahl, 1986). However, the Surgeon General stated that this type of fitness assessment carried an unacceptable risk of potential injury for participants over 30 years of age. In addition, the Surgeon General stated that the 2.4 km (1.5 mile) run was an inappropriate test of general physical fitness, as the minimum performance standard could be achieved by basically sedentary individuals who spent a few weeks preparing or did not prepare at all. As a result of these concerns, the 2.4 km (1.5 mile) test was discontinued in 1980 (Lee, 1992).

I. CF EXPRESS

In 1983, the CF EXPRES (EXercise PREScription) program was adopted by the CF. The CF EXPRES program was derived from the Canadian Standardized Test of Fitness and, in recent times, has been the primary means of evaluating the physical fitness of CF soldiers (CF EXPRES, 1983). The CF EXPRES program is comprised of four performance tests. Muscular strength was measured using combined grip strength scores from a handgrip dynamometer. Muscular endurance was measured using maximum number of situps and pushups in one minute. Aerobic fitness was determined using Canadian Aerobic Fitness Test (CAFT). The CAFT is a submaximal double-step test during which subjects step in time with a prerecorded audiotape. The prerecorded audiotape sets the stepping pace and also indicates when to stop and take a ten second pulse count. The pulse count is compared to a post-exercise heart rate table, in order to determine the soldier's ability to continue the test, which

consists of a maximum of three progressively demanding stages. After the soldier has completed his or her final stage, a final 10 second heart rate is determined and used in conjunction with an age and gender specific regression equation to calculate VO_2 max. Table 2 contains the minimum aerobic fitness standard for both male and female CF personnel (CF EXPRESS, 1989).

Table 2.
Minimum Aerobic Fitness Standard for Canadian Forces Personnel

Evaluation Item	Male		Female	
	<34 years	>35years	<34 years	>35 years
VO_2 max ($ml \cdot kg^{-1} \cdot min^{-1}$)	39	35	32	30

The CF has experienced problems with the CAFT, as it has been demonstrated that the CAFT test tends to overestimate the VO_2 max of unfit soldiers and tends to underestimate the VO_2 max of highly fit soldiers (Fitness Canada, 1987). Many submaximal VO_2 max tests, such as the CAFT, rely on the use of age predicted maximum heart rate and the established linear relationship between heart rate and work output. However, errors in measuring technique or in assumptions may lead to errors in VO_2 max prediction (Brooks et al., 1996). For example, a forty year old subject would have an age predicted maximum heart rate of 180 bpm (220 - 40 (age) = 180); however, if the subject had an actual maximal heart rate of 195 bpm, estimated VO_2 max would be underpredicted. These errors are greatest for those individuals who lie at either end of the fitness continuum.

Another problem with the CAFT is that only certain technicians are allowed to administer the test. For instance, CF Physical Education and Recreation (PE&R) staff are

exclusively permitted to administer the CAFT test to soldiers (CF EXPRES, 1989). Furthermore, usually only one soldier is tested at a time, which may not fulfil the time management needs of a large organization such as the CF.

According to the CF, the greatest shortcoming of the CAFT is the test's relatively poor relationship with the ability to perform occupational duties/tasks. Stevenson et al. (1992) found a nonsignificant correlation between VO_2 max, as predicted by the CAFT, and performance on occupationally-related military activities. The associated problems with the CAFT have prompted the CF to explore alternate methods of determining a soldier's aerobic fitness.

II. Occupationally-Related Fitness Tests

Many organizations including firefighters (Gledhill and Jamnik, 1992) and police officers (Rohdes and Farenholtz, 1992) have used physical performance standards for worker selection or evaluation. In the past, screening and evaluation processes have been based primarily on normative data, using generalized tests of fitness. Test batteries have often included tests such as the CAFT, hand grip dynamometry, body composition, and flexibility tests.

Recently, the trend has been toward developing task-specific or occupationally-related tests for applicant screening or incumbent testing, a trend largely based on legal and legislative pressures in response to females entering traditionally male-dominated occupations. Jackson (1994) reviewed legislative factors in the United States that are responsible for this trend, including civil rights legislation, equal employment guidelines, and the American disabilities act. The Canadian Human Rights Act (CHRA, 1985) is the

equivalent of the American legislation described by Jackson (1994).

The CHRA (1985) stated that in order to develop bona fide occupational requirements, tests should be based upon the following:

1. Identification of the essential tasks that make up the job by reviewing scientific literature, interviewing subject matter experts, and/or measuring the physical demands of the activities themselves.
2. Selecting or developing standardized representative tasks, in conjunction with management or experts, that are either the most demanding or are commonly performed.
3. Having incumbent members perform laboratory and/or simulated tests to evaluate the physiological requirements necessary to carry out the essential tasks.
4. Establishing standards, using statistical analysis, that meet but do not exceed the minimum requirements for the job.

In order to measure the ability of a soldier to perform occupational duties and meet the Canadian Human Rights legislation (CHRA, 1985), the CF has had the scientific community assist in designing, validating, and implementing bona fide occupational requirement tests. Stevenson et al. (1992), in conjunction with the National Defence Headquarters (NDHQ) Directorate, developed minimum fitness standards for CF EXPRES tests.

Common military tasks were selected, standardized, and then performed along with the CF EXPRES test battery. A random sample of CF personnel, representing a cross-section

of different occupational and fitness levels, was used and included 66 male CF personnel (mean age 24.1 years), 144 female CF personnel (mean age 25.2), 100 male CF personnel (mean age 41.4 and a range of 35 to 53 years), and 76 female CF personnel (mean age 38.4 with a range of 35 to 50 years). In addition to the CF EXPRES protocol, Stevenson et al. (1992) identified and operationally defined five common military tasks in order to determine minimum standards. The military tasks were defined as follows:

1. *Land Evacuation Task.* A soldier hauled a 40 kg load on a stretcher, with wheels attached, a distance of 0.75 km on an indoor cement track.
2. *Sea Evacuation Task.* Using a simulated ship staircase (1 flight) and a skid-mounted stretcher (80 kg), a soldier (wearing fire fighting protective clothing) pushed the stretcher 12.5 m, then moved the stretcher up and down the staircase.
3. *Entrenchment Dig Task.* A soldier moved 0.5 m^3 of crushed rock from one box into another box of similar dimensions (length 1.8 m, width 0.61 m, depth 0.46 m).
4. *Sandbag Carry Task.* A soldier lifted and carried as many 20-kg sandbags as possible over a 50 m distance in 10 minutes.
5. *Low/High Crawl Task.* Wearing combat fatigues, helmet, and carrying a replica FNCI rifle, soldiers low crawled (leopard) a 30 m distance, which was followed by a high crawl on hands and knees (45 m).

After Stevenson et al.'s (1992) subjects completed both the CF EXPRES protocol and the five occupationally-related tasks, performance results were analyzed using Pearson

Product Moment Correlation and regression analysis. Table 3 contains the minimum physical fitness requirements that CF personnel must obtain on the yearly CF EXPRES test, according to Stevenson et al.'s (1992) results.

Table 3.
CF EXPRES Minimum Physical Fitness Standards

Evaluation Item	Male		Female	
	<34years	>35 years	<34years	>35 years
VO_2 max (ml • kg^{-1} •min^{-1})	39	35	32	30
Hand grip (kg)	75	73	50	48
Pushups (#)	19	14	9	7
Situps (#)	19	17	15	12

Singh et al. (1991) performed a similar investigation to that of Stevenson et al. (1992). However, the purpose of Singh et al.'s (1991) study was to develop occupationally-related fitness tests for the CF. Singh et al.'s (1991) methodology was based on Canadian Human Rights Act and included:

1. Identification of the most physically demanding common tasks through a review of the literature and consultation with CF commanders.
2. Identification of the physical capabilities required to complete the selected work tasks successfully and development and/or selection of appropriate laboratory tests that predict the capability necessary to complete these tasks.
3. Quantification of physical capacities based on laboratory test and field task performances.

4. Statistical analysis of data to determine the population performance characteristics on different tests and to predict relationships between laboratory and field task variables.

5. Determination of acceptable levels for performance standards.

Given that under certain conditions, any military personnel may be called upon to perform infantry duties (Lee, 1992), Singh et al. (1991) selected the following tasks, which are representative of activities routinely performed by infantry soldier.

1. The casualty evacuation required a soldier to carry, using a Fireman's Carry technique, another soldier of approximately the same height and weight 100 m around the perimeter of a gymnasium floor at a maximum walking speed. Recommended cut-off time was 60 s.

2. The ammunition box lift involved lifting, one at a time, a total of 48 boxes (20.9 kg) and placing them on a table 1.3 m in height. Using a heart rate monitor, the soldier worked at a rate corresponding to a maximum of 70% of VO_2 max, which had previously been determined via a direct measure maximal treadmill test. Recommended cut-off time was 300 s.

3. Maximal jerry-can carry involved carrying a jerry-can filled with water (21 kg) a distance of 35 m and then emptying it into a funnel 1.3 m off the ground. The subject would then return the empty can to the start line and pick up another jerry-can full of water and repeat the procedure. The procedure was repeated three times. Recommended cut-off time was 300 s.

4. A 13 km weight load march, wearing full fighting order and carrying a 24.5

kg backpack, was completed at a pace of 5.3 km • h^{-1}. The recommended cut-off was pass or fail.

5. The maximal slit-trench dig required the soldier, using a standard army issue shovel, to remove, at a maximum rate, 0.5 m^3 of standard gravel from one side of a slit-trench simulator to the other side. Recommended cut-off time was 360 s.

Each occupational task was analyzed to determine which physiological factor(s) contributed most to the performance of the task. In the successful completion of all the tasks, three physiological components were identified as most important: aerobic fitness, muscular strength, and muscular endurance (Lee et al, 1991, 1992; Singh et al, 1992, 1993; Chahal, 1991).

III. Aerobic Demands of Slit-Trench Digging

The fox hole or slit-trench is a shallow dugout which a soldier can use for protection from incoming enemy fire. The slit-tench has been used by the military for decades; after all, trenches can be dug, using only a shovel, by an individual soldier in almost any situation. Trench digging is considered to be a common task that any soldier may be required to perform at any time. Given the importance of trench digging, the CF has standardized and utilized this task as an occupationally-related test of military fitness.

Simulated slit-trench digging uses two metal boxes welded together, each with dimensions of 1.8 m in length, 0.6 m in width, and 0.45 m in depth (Figure 1). Soldiers remove 0.5 m^3 of standard gravel from one side of a slit-trench simulator to the other side, using an army issue shovel, at the maximum rate possible. The crushed rock is usually

Figure 1 Slit-Trench Digging Task

dampened with water to prevent dust suspension and thus reduce breathing discomfort.

Chakraborty et al. (1974) were the first to investigate the aerobic demands of trench digging. They determined that a soldier's relative oxygen uptake, while performing this task, was 29.1 ml • kg^{-1} • min^{-1} (1.5 l • min^{-1}), which represents an intensity equivalent to 69% of VO_2 max (Stevenson et al., 1988).

One of the largest and most extensive studies of trench digging was conducted by Singh et al. (1991), who studied the slit-trench digging performance of 116 male soldiers (mean age 25.5 ± 5.8 years). The mean time that subjects took to complete the digging task was 262.04 ± 44.54 s. Based on regression analysis, in order to successfully perform the trench digging task in less than 360 s, a relative VO_2 max of 38.6 ml • kg^{-1} • min^{-1} (3.12 l • min^{-1}) was necessary, which corresponded to approximately 74% of VO_2 max of the soldiers tested. Correlation results demonstrated that absolute and relative VO_2 max significantly ($p<0.05$) correlated with trench digging performance ($r=-0.48$ and $r= -0.36$, respectively). However, the multiple correlation coefficient indicated that other factors such as leg peak power and static trunk extension strength, in combination with VO_2 max, accounted for 36% of slit-trench digging performance.

Stevenson et al. (1992) also examined trench digging; performance time for 66 male soldiers (mean age 24.1 years) was 252.8 ± 49.8 s. In contrast to the findings of Singh et al.'s (1991) investigation, the results of Stevenson et al.'s (1992) study showed a non-significant correlation ($r= -0.16$) between predicted VO_2 max, using the CAFT method, and slit-trench digging performance.

It has been demonstrated that trench digging performance is significantly related to

direct measures of VO_2 max (Singh et al., 1991). However, test scores based on the current screening tool used by the CF for aerobic fitness (the CAFT) does not significantly correlate with trench digging performance (Stevenson et al., 1992), which reinforces the need to adopt a more accurate predictive VO_2 max field test.

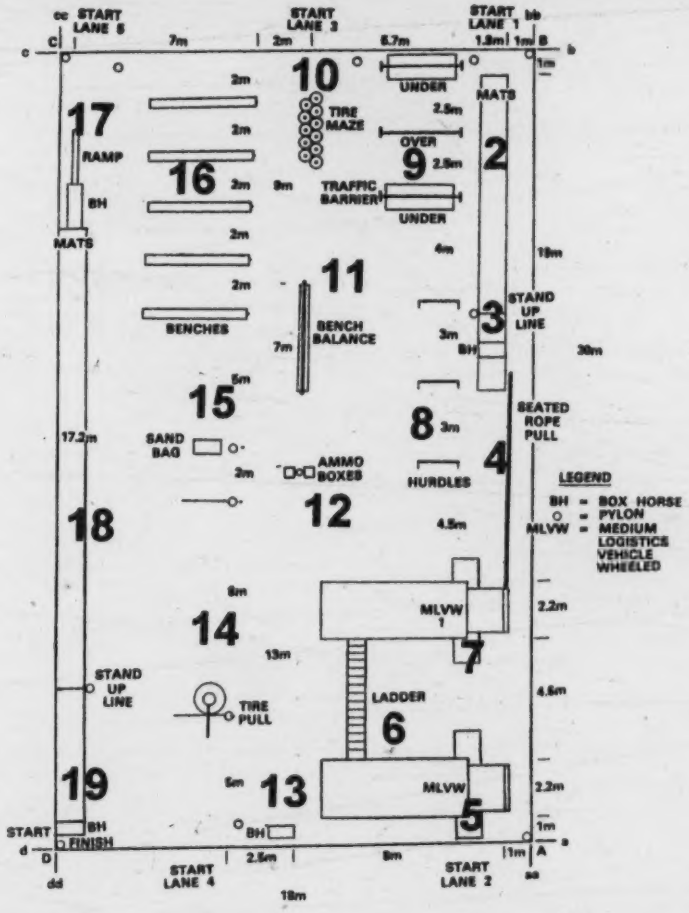
IV. Perspectives on the Indoor Standardized Obstacle Course (ISOC)

For many years, the obstacle course has been used by the military to test a soldier's physical capability to perform in battlefield situations. The USSR (Pratt, 1987), Great Britain (Army Council, 1958), and the United States (Department of the Army, 1980) have used obstacle courses to evaluate various fitness components of their personnel. However, not all tasks performed in previous obstacle courses are representative of the demands placed upon modern soldiers. In addition, there is little information describing the physiological demands of obstacle course performance (Kimick, 1987).

Jette et al. (1989) developed a 19-item Indoor Standardized Obstacle Course (ISOC) which consists of running, crawling, scaling, pulling, lifting, carrying, and pushing, these activities were selected, based on commonality in the military (Figure 2). Jette et al. (1990) arranged the tasks in a sequential order through trial and error until a scheme was determined that appropriately tested both the upper and lower body as well as the aerobic and anaerobic systems (Jette et al., 1989). From the start line, a soldier would run/jog 1.5 laps (135 m) around the perimeter of the course until reaching the start of lane one. The soldier then proceeded through the required five lanes, completing all tasks. The ISOC was constructed indoors to reduce environmental conditions that may have affects on ISOC

performance (Pratt, 1987; Department of the Army, 1980; Army Council, 1958). The purpose of the ISOC was to assess a number of physiological factors at once as subjects executed military tasks similar to those regularly encountered on duty. Forty-three healthy male soldiers (21 to 31 years of age) performed a series of laboratory tests, including aerobic power (51 ± 6.7 ml • kg^{-1} • min^{-1} or 3.7 ± 0.5 l • min^{-1}), anaerobic lactic power (ALP), anaerobic alactic power (AAP), muscular strength, muscular endurance, and a series of anthropometric measurements. Subjects performed the ISOC on three separate occasions in order to ensure that they were thoroughly familiarized.

Based on the subject's best ISOC time, Jette et al. (1990a) demonstrated a significant correlation between ISOC performance time and absolute and relative VO_2 max (r=-0.69 and r=-0.73, respectively). Stepwise multiple regression analysis indicated that 54% of ISOC performance could be accounted for by VO_2 max. In addition, Jette et al. (1990a) determined that in order for a 70 kg soldier to complete the ISOC in 317 s, he would require a VO_2 max of 3.57 l • min^{-1} or 51.1 ml • kg^{-1} • min^{-1}. Jette et al. (1989; 1990a) concluded that the ISOC provided a practical procedure for assessing the fitness (readiness) of infantry soldiers and of soldiers in other field units in the CF.



1. Jog/run-1.5 lap run (135 m)
2. Leopard crawl (9 m)
3. Scale wall (1.07 m)
4. Seated rope pull (5 m)
5. Low crawl under vehicle
6. Horizontal ladder traverse (7.3 m)
7. Low crawl under vehicle
8. Jump over hurdles (0.76 m) x 3
9. Thread hurdles (under/over/under) (0.76 m) x 3
10. Tire maze (11 tires)
11. Balance beam (3.7 m in length)
12. Ammo box (21 kg) lift & carry (40 m)
13. Scale wall (1.38 m)
14. Tire pull (68 kg, 16 m)
15. Sandbag (20 kg) lift and carry (60 m)
16. Jump low hurdles (0.30 m) x 5
17. Ramp (1.1 m), run, jump and roll
18. Leopard crawl (17 m)
19. Scale wall (1.3 m)

Figure 2. Schematic of the Indoor Standardized Obstacle Course. (Modified from Kimick, 1987)

V. 20 Meter Shuttle Run (20MSR)

The 20MSR (Figure 3) evolved from the University de Montreal Track Test (UMTT). The UMTT was developed to predict VO_2 max from the maximal running speed attained, based on Shephard's (1968) calculations of the energy cost of running (Leger and Boucher, 1980).

The UMTT was conducted on a 166.7 m indoor track with inclined curves; red pylons were placed around the perimeter of the track at every quarter section. Subjects were required to run around the perimeter of the track, attempting to reach the next red pylon in time with a loud beep, which was emitted from a stereo playing a prerecorded audio tape. Initial running speed was set at 6.0 km · h^{-1}; running speed was increased by 1.2 km · h^{-1} every two minutes. If the subject was unable to keep pace with the beeps and fell behind the pace by 30 feet, or if the subject became exhausted and could not continue, the test was terminated. The maximal speed attained by the subjects was recorded and used to calculate VO_2 max values.

In order to validate the UMTT, five separate investigations were conducted by Leger and Boucher (1980). The first experiment compared predicted UMTT VO_2 max values with direct measures of VO_2 max (Balke protocol). Six untrained (35.2 ± 3.7 years) and nine trained (22.0 ± 3.8 years) subjects were used. For the entire group, the mean VO_2 max results using the two different protocols were not significantly different. However, the Balke protocol, unlike the UMTT, yielded higher VO_2 max values for trained subjects as opposed to untrained subjects.

In the second experiment, ten additional subjects (20 ± 1.4 years), including one female,

participated. Using an inclined treadmill test protocol, comparisons were made between directly measured VO_2 and UMTT values. VO_2 max scores were very similar for the two protocols, with a correlation coefficient of r=0.96 (Leger and Boucher, 1980).

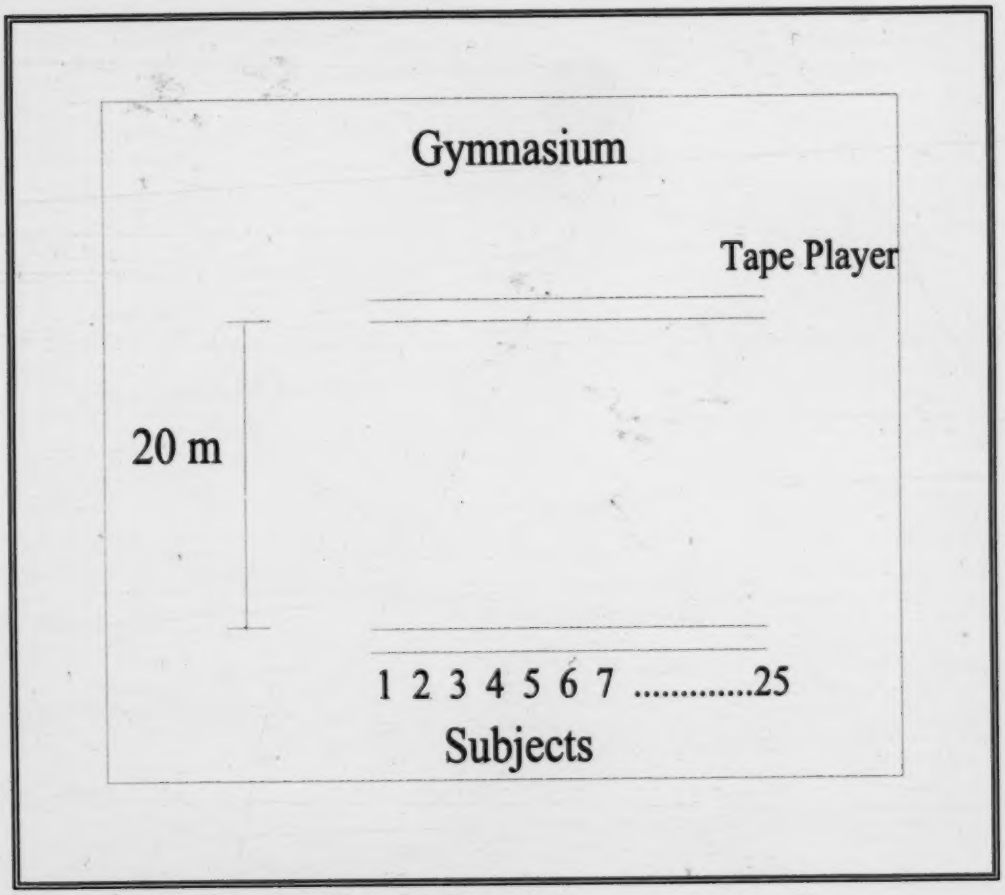


Figure 3. Schematic of the 20 m shuttle run test

In the third investigation, in which subjects consisted of 7 males (20.6 ± .98 years), VO_2 max values predicted from the UMTT were compared with VO_2 max values obtained by the retroextrapolation method (Leger et al., 1980). Retroextrapolation involves the

collection of three to four 20 second expired air samples, using a Douglas bag, from a subject immediately (within 3 seconds) upon completion of an exercise bout. Using standard gas analysis methods, VO_2 was determined from the collected expired air samples. An exponential least-squares regression of the O_2 recovery curve, based on the three to four expired air samples collected, was used to compute VO_2 max. The correlation between the predicted VO_2 max derived from the UMTT and the retroextrapolation method was r=0.66 (Leger and Boucher, 1980).

The fourth experiment involved a reliability test of the UMTT protocol. Sixty subjects (19-40 years of age) performed the UMTT on two separate occasions, which were separated by 10 days. A correlation coefficient of r= 0.97 was found (Leger and Boucher, 1980).

A fifth experiment included the UMTT, Åstrand-Rhyming bicycle test, Canadian Aerobic Fitness Test (CAFT), and 12-min run test. Twenty-five physical education students (male and female) performed the tests at a rate of one test per week. Correlation coefficients between the UMTT and the other tests were 0.71 (Åstrand-Rhyming), 0.40 (CAFT) and 0.84 (12-min run) (Leger and Boucher, 1980).

Leger and Lambert (1982) developed the 20MSR, which was based on the same principles as the UMTT. Although the UMTT protocol was valid and reliable test of VO_2 max, performing the UMTT in an environmentally controlled location such as a gymnasium was not safe due to the high speeds generally achieved during the final stages. Therefore, Leger and Lambert adapted the UMTT protocol so that it involved running back and forth over a 20 m distance. Initially, the starting speed for the 20MSR was set at . After a series

of pilot studies were conducted, the experimental protocol was modified, in which the 20MSR started at 8.5 km • h^{-1} and increased by 0.5 km • h^{-1} every two minutes. Runnning/jogging pace was set using a prerecorded audio tape similar to that used in the UMTT. The 20MSR was terminated if the subject became exhausted or if, on two successive turns, the subject was more than 3 meters away from the 20 m line at the sound of the beep (Leger and Boucher, 1980).

To validate the 20MSR, a series of experiments was conducted, similar to the process used to validate the UMTT. Correlation coefficients were computed between predicted VO_2 max using the 20MSR and retroextrapolation method with direct measures of VO_2 max using the Balke test. Results of the validation study demonstrated that at the end of the Balke protocol, VO_2 max determined by the retroextrapolation method (42.78 ± 10.76 ml • kg^{-1} • min^{-1}) and directly measured VO_2 max (42.65 ± 10.03 ml • kg^{-1} • min^{-1}) had a correlation of 0.97. In addition, directly measured VO_2 max values during the Balke protocol yielded a correlation of r=0.92 with VO_2 max values obtained by retroextrapolation method at the end of the 20MSR. To predict VO_2 max, using the 20MSR, the following regression equation was developed y = 5.87x - 19.458, where y is equal to VO_2 max (ml • kg^{-1} • min^{-1}), and x is maximal speed attained (km • min^{-1}) (Leger and Boucher, 1980).

In 1984, Leger et al. determined that using two minute stages did not adequately account for running efficiency. The protocol for the modified 20MSR was the same as previously presented (Leger and Lambert, 1982), except running speed increased by 0.5 km • h^{-1} each minute instead of every two minutes. Validity and reliability of the new 20MSR protocol was determined in a subsequent investigation. Using 53 males and 24 females, 19

to 47 years of age, a correlation of 0.95 was reported between VO_2 max predicted by the 20MSR and by direct measures of VO_2 max (Leger et al., 1989).

To further validate the 20MSR, 77 participants (19-47 years of age) performed a direct VO_2 max test using a graded maximal treadmill test. VO_2 max values were compared to VO_2 max values derived from the 20MSR maximal speed attained, retroextrapolation method at the end of the 20MSR, Canadian Aerobic Fitness Test (CAFT), and the retroextrapolation method at the end of the treadmill test. The correlation coefficients in Table 4 emphasize the 20MSR's ability to accurately predict VO_2 max, and the CAFT protocol's poor ability to predict VO_2 max.

Table 4.
Correlation Coefficients (r) relating the VO_2 max of a multistage treadmill test to the other VO_2 max tests (n=77)

	Comparison of Direct Measure of VO_2 max on a Treadmill with			
	MSA-VO_2 max	SR-VO_2 max	CAFT-VO_2 max	TR-VO_2 max
r	0.90	0.89	0.61	0.92

Legend: MSA - VO_2 max predicted from the 20MSR Maximum Speed Attained (MSA); SR - retroextrapolation at the end of the 20MSR; CAFT - VO_2 max predicted from the CAFT step test; TR - retroextrapolation method on the treadmill.

Montgomery et al. (1992) examined the validity of three predictive VO_2 max tests – the 20MSR (Leger and Lambert, 1982), a modified CAFT (Reid et al., 1985), and an incremental cycle ergometer test (Åstrand, 1960) – by comparing predicted VO_2 max with direct measure of VO_2 max, carried out during uphill treadmill running (Bruce et al., 1973). Ten male adults (20 to 35 years of age) participated in the study. Each test was performed on five separate occasions. Correlation coefficients were calculated between predicted VO_2

max and directly measured VO_2 max. The correlation coefficients between directly measured VO_2 max and the 20MSR, CAFT, and cycle ergometer test were r=0.92, r=0.79, and r=0.60, respectively; thus, direct measures of VO_2 max verify the high validity of the 20MSR.

The 20MSR has been developed using rigorous scientific principles and methods. Extensive examination to verify the validity and reliability of the 20MSR, as a predictor of VO_2 max, has been established. The 20MSR also has characteristics considered favourable by CF administrators and commanders, including ease of administration, need for little specialized equipment, ability to test a large group simultaneously, cost-effectiveness, and little need for technical expertise in order to administer the test.

F. SUMMARY

Aerobic fitness is important for successful performance of various military activities, a fact which, during the CF's history, has led to the development and use of several different aerobic fitness tests. Previous tests used by the CF have had validity, practicality, and cost limitations. CF administrators are attempting to address these issues by implementing the 20MSR. The 20MSR has been validated as a reliable test of VO_2 max. In addition, it has favourable characteristics as a means for testing CF personnel. However, before the 20MSR can be adopted by the CF, it first needs to be validated in the military setting in order to comply with guidelines set forth by the Canadian Human Rights Commission (1978).

CHAPTER III

METHODS AND PROCEDURES

A. SUBJECTS

Seventy-five male soldiers from the Canadian Forces Base Calgary (Alberta) volunteered to participate in this study. Each subject completed a Health Appraisal Questionnaire (Appendix A1) and signed an informed consent form (Appendix A2) before participating in this study. The sample was made up of soldiers from a variety of occupational groups, including members of the Princess Patricia's Canadian Light Infantry (PPCLI), who are front-line infantry soldiers, and of the Lord Strathcona Horse (LDSH), which is the armoured vehicle detachment of the infantry. Also included were members of the signal squadron, whose main responsibility is communication for the infantry, and the service battalion, whose occupation involves repair and maintenance of combat vehicles and machinery.

B. FAMILIARIZATION

A familiarization session was completed prior to testing in order to minimize performance differences due to skill or learning effects. On a separate day prior to testing, each subject practiced and performed all tests at least once in exactly the same fashion as the actual tests.

C. MEASURES

The following measures were taken: 20 meter shuttle run, slit-trench digging performance time, ISOC performance time, and anthropometric measures.

20 METER SHUTTLE RUN (20MSR)

The 20MSR was conducted in a drill hall on a gym floor as per the layout depicted in Figure 3. Subjects performed this test in combat fatigues (1.2 kg) and court shoes. An audio cassette, played on a portable stereo, provided instructions on how to perform the test. As recommended by Leger and Rouillard (1983), the portable stereo was calibrated before each test for correct playback speed.

On the word "go," the subjects would walk/run, reaching the 20 m mark at approximately the same time the cassette beeped; subjects then reversed direction and travelled back to the original mark (20 m) until the cassette beeped again. Initial speed was set at 8.5 km • h^{-1}. This process continued while the tempo increased every minute by 0.5 km • h^{-1} . If the soldier was unable to keep pace with the beep and missed making it to the line on two consecutive occasions, the tester would stop the test for that individual. The last stage attained was recorded as the final score. This score was converted to a measure of relative VO_2 max, using the standardized table provided (Leger et al., 1988, Appendix B1).

SLIT-TRENCH DIGGING

Two metal boxes welded together, each with the following dimensions (1.8 m in length, 0.6 m in width, and 0.45 m in depth), were used for the slit-trench digging task (Figure 1). Subjects removed 0.5 m^3 of standard gravel (less than one centimetre in diameter) from one

side of the simulator to the other side, using an army issue shovel, at the maximum rate possible. The crushed rock was lightly dampened with water to prevent dust suspension and reduce breathing discomfort.

On the command "Start" (timing commenced), the subject began to pitch the gravel as quickly as possible from one side of the simulator to the other side; the subject continued until less than one handful of gravel remained in the depleted side of the trench, at which point the tester said "Stop" (timing ceased). Time was recorded to the nearest second.

INDOOR STANDARDIZED OBSTACLE COURSE (ISOC)

To maintain climactic conditions during testing, the ISOC was constructed inside a standard military drill hall. Using readily available materials from Canadian Forces Base Calgary, the course was assembled to the specifications shown in Figure 2 (Kimick, 1987). The familiarization session included briefing, demonstrating, and practicing the ISOC. Practice sessions were allowed to continue until the soldiers believed they were performing the ISOC to the best of their ability.

Wearing combat fatigues (1.2 kg) and boots (1.7 kg), the soldiers performed the ISOC as quickly as possible. Performances were hand timed by two testers, and the average time was recorded to the nearest second. Testers were located at various points along the course to ensure that the soldiers maintained the proper sequence of events and to provide verbal encouragement.

BODY COMPOSITION

I. Height

Height was measured with a metric wall-tape and a set square. Subjects stood erect, bare foot, and with heels together in contact with the wall. Arms were held by the side of the body, while subjects looked straight ahead. Recorded height was measured to the nearest 0.5 cm (CF EXPRES, 1989).

II. Weight

For weight measurement, subjects wore light clothing (T-shirt and shorts) and were without footwear. Subjects stood erect on a beam balance scale that was placed on a hard flat surface. Weight was measured to the nearest 0.1 kg (CF EXPRES, 1989).

III. Skinfold

Skinfold measurements, including triceps, biceps, subscapular, iliac crest, and calf were taken using Harpenden Calipers. All measurements were taken according to the CF EXPRES protocol (1989) and recorded to the nearest 0.2 mm. Each of the five skinfold sites were measured once and then repeated; a third measurement was taken if the difference between the first two readings was greater than 0.4 mm. If three measurements were taken, the mean of the two closest measures at a site was calculated and recorded; however, if two measures were equidistant from the middle measure, then the middle value was recorded.

IV. Percent Body Fat

Using the Durnin and Womersly (1974) method, percent body fat was calculated from the sum of four skinfold measurements (triceps, biceps, subscapular, and iliac crest).

V. Body Mass Index (BMI)

Body mass index was calculated by dividing the subjects' body weight (in kg) by the square of their height (in m^2).

D. PROCEDURES

The following testing schedule (Table 5) was used so as to operate within the CF's schedule. During the morning session, body composition, slit-trench digging, and 20MSR were performed. In the afternoon session, subjects performed the ISOC. Appendix C1 and C2 contains a detailed schedule of the testing events for both the morning and afternoon sessions.

Table 5.
Testing Schedule for Laboratory and Occupational Tasks

Session	Monday	Tuesday	Wednesday	Thursday	Friday
morning	Service Batt.	PPCLI	Signal Squad	LDSH	
afternoon		Service Batt.	PPCLI	Signal Squad	LDSH

E. STATISTICAL ANALYSIS

SPSS® (SPSS® Inc., 1992) computer software was used to compute descriptive statistics (mean, standard deviation, and range), Pearson Product Moment Correlation (PPMC), and regression analysis. The PPMC was calculated to establish the relationships between 20MSR scores and occupational task performance scores, as well as the other variables examined. The use of correlation procedures involves the assumption of a linear relationship between the variables (Smith and Glass, 1987), an assumption that was confirmed by graphing the raw

data. In addition, simple linear regression analysis was performed to predict ISOC and trench digging performance from 20MSR scores. The alpha level was set at $p < 0.05$.

CHAPTER IV

RESULTS AND DISCUSSION

The following chapter has been divided into sections. Section A details the descriptive statistics making some reference to inferential statistics. Section B details the relationship between the 20MSR, slit-trench digging, and ISOC. Section C contains a summary of the results and discussion. For some subjects, data for each of the various measures and tests was not collected.

A. DESCRIPTIVE STATISTICS

I. Physical Characteristics of the Subjects

Seventy-five male Canadian soldiers participated in the present study. The mean age of the subjects was 26.7 ± 4.5 years, with a range from 20 to 38 years (Table 6). The age of the subjects in the present investigation was comparable to that of subjects in other studies in which combat arms personnel performed occupationally-related military activities (Singh et al., 1991 (25.0 ± 5.8 years); Jette et al., 1990a (25.6 ± 3.0 years); Stevenson et al., 1992 (24.1 years)).

The mean height of the subjects in the present investigation was 178.3 ± 6.88 cm. Compared to normative data for Canadian males, the subjects were slightly above average in height (55th and 60th percentile) for their age category (Fitness Canada, 1987). Compared to a cross-section of Canadian military personnel (n=17,098), mean height was similar to the average male CF soldier (176.1 ± 6.9 cm) (Jette et al., 1990b). In addition, height was similar to that of subjects in other studies of CF combat arms personnel (Singh et al., 1991; Jette et al., 1990a; Stevenson et al., 1992), in which height ranged from 176.2 to 177.4 cm.

Body weight for the subjects in the present study was 83.5 ± 13.1 kg. In comparison with Canadian males of similar age, mean body weight of the subjects was between the 70th and 80th percentile (Fitness Canada, 1987). In relation to CF personnel, the subjects had a mean body weight substantially greater than the average male CF personnel (78.0 ± 10.9 kg) (Jette et al., 1990b); however, mean body weight of the soldiers in the present investigation was comparable to senior military officers (mean age 43.1 years) mean body weight, which was 82.7 ± 9.2 kg (Wright et al., 1994). Still the mean body weight of the subject in the present study was substantially higher than in other studies of combat arms soldiers (Singh et al., 1991 (79.4 ± 10.6 kg); Jette et al., 1990a (73.8 ± 8.5 kg); Stevenson et al., 1992 (77.0 ± 11.2 kg)).

Table 6.
Descriptive Characteristics of Subjects

Variable	n	mean	s.d.	minimum	maximum
Age (years)	67	26.7	4.53	20	38
Height (cm)	75	178.3	6.88	164.0	193.5
Weight (kg)	75	83.5	13.1	60.5	135.3
Body Fat (%)	62	25.3	4.76	16.2	34.6
SOS* (mm)	64	100.9	36.8	38.0	190.9
BMI (kg/m^2)	75	26.2	3.4	20.2	38.5

* Triceps + Biceps + Subscapular + Iliac Crest + Medial Calf

In the present investigation, the mean sum of five skinfold measures was 100.9 ± 36.8 mm. Compared to Canadian population norms for males of similar age, these skinfold results fall below the 5th percentile (Fitness Canada, 1987). In the only other study of military personnel reporting results for these five skinfold measures, Singh et al. (1991), in his study of combat arms personnel, reported a much lower sum of the five skinfold measures, with a mean of 52.1 ± 16.1 mm.

Mean percent body fat of the subjects in the present investigation was 25.3 ± 4.76%. Other studies of combat arms personnel reported lower body fat percentages. Gordon et al. (1986), utilizing the sum of four skinfolds to calculate percent body fat, reported 13.6 ± 3.2%; Singh et al. (1991) and Knapik et al. (1990), utilizing an underwater weighing technique, reported a mean percent body fat of 18.4 ± 5.9% and 14.1 ± 6.9%, respectively. However, Knapik et al. (1990) and Gordon et al. (1986) utilized younger subjects (19.2 ± 3.2 and 22.0 ± 3.0 years, respectively) than the subjects in the present investigation (26.7 ± 4.53 years). The skinfold and body fat percentage data indicate that the subjects in the present study had considerably greater levels of body fat than did soldiers from other similar investigations. In fact, subjects in the present study had percent body fat values comparable to that of senior military officers (24.4 ± 5.1%) (Wright et al., 1994).

The average body mass index (BMI) value for subjects in the present investigation was 26.2 ± 3.4 kg/m^2. These results were higher than previously measured BMI values reported for a cross-section (n=17,098) of male CF personnel (25.1 ± 3.1 kg/m^2) (Jette et al., 1990b). However, the subjects in the present study had considerably higher BMI values when compared to other combat arms soldiers; Kimick (1987) and Drabik et al. (1989) reported

BMI values of 23.8 kg/m^2 and 23.2 kg/m^2, respectively. The subjects in the current study had BMI values slightly greater than those of senior military personnel (25.6 ± 2.2 kg/m^2) (Wright et al., 1994). Thus, although subjects in the present investigation were of similar age and height to subjects in other studies involving combat arms personnel, their mean body weight, sum of skinfolds, percent body fat, and BMI were found to be substantially greater than those of other combat arms soldiers (Jette et al., 1990a, 1990b; Singh et al., 1991). There are a number of possible explanations for these differences.

One explanation may be that the subjects in the present investigation had been exposed to military training programs different from those experienced by the subjects in previous investigations (Jette et al., 1990a, 1990b; Singh et al., 1991). Although the CF EXPRES (1992) program manual provided specific training programs to develop a soldiers physical fitness it did not have programs that specifically address body composition issues such as excessive body fat. Recently, CF commanders, who may have limited knowledge in the area of physical fitness, have been made responsible for the development and administration of physical conditioning programs for his or her soldiers (Singh et al., 1994). Some commanders, as compared to other commanders, may emphasize different physiological components in their training regimes, which may in turn result in varied physical fitness levels amongst CF personnel. In 1986, Gordon et al., recognizing a need for greater emphasis on the physical conditioning of military personnel, suggested that the present military training programs emphasized specialized task training, that reduced the amount of time devoted to physical conditioning.

The need for standardized physical training programs has been recognized by the CF

Directorate of Physical Education and Recreation Amenities. The Directorate stated that CF commanders lacked standard, easily administered, and scientifically-based physical training programs that produce or maintain sufficient levels of physical fitness. The Directorate further noted that the physical training programs need to be specific to the demands of military duty, while maintaining the physical characteristics associated with a healthy individual (Singh et al., 1994). Thus, subjects in the present study may have been subjected to military training programs ineffective in reducing body fat in comparison to the programs experienced by soldiers in past studies (Jette et al., 1990a; Singh et al., 1991; Stevenson et al., 1992).

Another possible explanation could be the time of year in which the subjects in the current investigation were tested. Subjects were tested in early January, not long after return from winter (Christmas) vacation. While on vacation, the soldiers may have altered their eating habits. In North America, holidays such as Christmas and Thanksgiving are generally associated with consuming foods that are high in calories and fat, which in turn may increase caloric intake. Klesges et al. (1989) examined eating behaviours of 65 adults (31 male and 34 female) prior to, during, and after the Thanksgiving holiday weekend. Dietary records revealed that the subjects' caloric intake significantly ($p<0.05$) increased from pre-holiday levels of 2,159 kcal to holiday levels of 2,440 kcal. Using 23 healthy males (22.9 ± 0.4 years of age) as subjects, Roberts et al. (1993) demonstrated that an increase of approximately 966 kcal/day resulted in a 118 g/day deposition of fat and protein, which resulted in a gain of 2.25 kg over a 20 day period. Klesges et al. (1992) determined that increased dietary fat was significantly related to increased body weight (i.e., body fat) in males. The subjects in the

present investigation may have exhibited typical holiday eating behaviours, along with decreased physical activity patterns during their vacation period (approximately two weeks), which may have contributed to an increased quantity of body fat.

The high mean body fat percentages, as exhibited by the subjects in the present study, gives rise to concerns among CF administrators. Excessive body fat has been linked to increased risk of coronary heart disease, stroke, hypertension, diabetes, gallbladder disease, and back pain (Brooks et al., 1996). In addition, excessive body fat may impair a soldier's ability to adequately perform his or her specific military duties (Jette et al., 1990b). Soldiers with excess body fat place a greater demand on their cardiorespiratory system and on muscular strength and endurance when performing certain military tasks (Buskirk and Taylor, 1957). Reducing a soldier's ability to perform military duties may pose a threat to his or her safety, which is a concern for CF administrators. Jette et al. (1990b) stated:

> ...an individual with excess weight [body fat] may severely jeopardize his or her personal safety as well as the safety of other members of the unit. The personal safety of overweight personnel can be further jeopardized if they are called upon to don protective warfare clothing and masks, under circumstances demanding physical and psychological exertion (p. 123).

In addition, Jette et al. (1990b) stated that the safety issue for overweight soldiers may be magnified if an emergency situation calls for speed and agility.

Finally, the CF is concerned with the appearance and image their soldiers portray. Commanders have stated that overweight personnel do not project a desirable image of the military or give the impression that the overweight soldiers possess the essential characteristics to meet the physical demands of military duty (Jette et al., 1990b).

II. 20 Meter Shuttle Run Performance (20MSR)

Mean 20MSR performance time for subjects in this investigation was 7.02 ± 1.71 min, resulting in a mean relative VO_2 max of 41.7 ± 5.12 ml · kg^{-1} · min^{-1} and a mean absolute VO_2 max of 3.44 ± 0.05 l · min^{-1} (Table 7).

Table 7.
Descriptive Statistics for the 20 Metre Shuttle Run Performance

Variable	n	mean	s.d.	minimum	maximum
Stage (min)	71	7.02	1.71	3.00	11.0
VO_2 (ml · kg^{-1} · min^{-1})	71	41.66	5.12	29.6	53.6
VO_2 (l · min^{-1})	71	3.44	.046	2.60	4.93

In comparison to Canadian population norms, mean relative VO_2 max values for subjects in the current study ranged from the 35th to 45th percentile for males of similar age (Fitness Canada, 1986). In comparison to other combat arms personnel (Jette et al., 1990a; Singh et al., 1991; Stevenson et al., 1992), subjects in the present study had lower relative and absolute VO_2 max values. Mean relative VO_2 max values for the subjects in this study were 6.1 to 11.3 ml · kg^{-1} · min^{-1} (12.8 to 17.5%) lower than the values reported by other studies, while mean absolute VO_2 max values were lower by 0.23 to 0.77 l · min^{-1} (6.3 to 18.3%) (Jette et al., 1990a; Singh et al., 1991; Stevenson et al., 1992).

A number of trends for VO_2 max values have been found in studies of CF personnel. Young soldiers tended to have higher VO_2 max values than older veteran soldiers. Gordon et al. (1986) and Hermanson (1978) reported VO_2 max values for 19 and 21 year old soldiers

to be 53.1 and 55.5 ml · kg^{-1} · min^{-1}, whereas senior military officers (mean age 43.1 years) had a mean VO_2 max value of 44.9 ml · kg^{-1} · min^{-1} (Wright et al., 1994). Another trend exhibited among CF personnel is that combat arms personnel tended to have higher VO_2max values than other groups of military personnel. Singh et al. (1991) and Jette et al. (1990a) reported mean VO_2 max values of 52.2 and 50.5 ml · kg^{-1} · min^{-1}, respectively, for infantry personnel, while a cross-section of 17,098 male CF personnel had a mean VO_2 max of 46.0 ml · kg^{-1} · min^{-1} (Jette et al., 1990b). Subjects in the present investigation were younger combat arms personnel; however, they exhibited relative VO_2 max values similar to older non-combat personnel.

In fact, nearly 36% of the subjects in this study were below the CF minimum aerobic fitness standard of 39.0 ml · kg^{-1} · min^{-1} (CF EXPRES, 1989). In addition, 71% of the soldiers were below the minimum aerobic requirement (45 ml · kg^{-1} · min^{-1}) that Daniels et al. (1984) and Gledhill and Jamnik (1992) reported as necessary to properly perform military duties.

Possible explanations why the subjects in the present study had fairly low VO_2 max values may be related to inadequate physical training programs, seasonal variation, detraining effects of vacation, or excess body fat. As discussed earlier, the Directorate of Physical Education and Recreation has concerns that CF fitness training programs may be inadequate to develop or maintain desirable physical fitness characteristics in areas such as aerobic fitness. The CF EXPRES program was developed in order to meet the exercise prescription needs of CF personnel. Aerobic fitness (VO_2 max) was estimated by using the Canadian Aerobic Fitness Test (CAFT) and measuring post-exercise heart rate upon completion of an exercise stage. After the fitness tests were completed, a Physical Education and Recreation

(PE&R) staff member calculated VO_2 max and prescribed an individual exercise program for the soldier. The CF EXPRES operations manual (1992) provided detailed information on how aerobic exercise programs were to be developed. The intensity for aerobic exercise (i.e., target heart rate zone) was determined from the final stage attained on the CAFT. Target heart rate zone (THRZ) was described as a percentage of maximal heart rate (220 - age = max heart rate). Soldiers who completed one stage on the CAFT were prescribed a THRZ of 50% to 60% of maximal heart rate (30% to 42% of VO_2 max). Soldiers who completed two stages on the CAFT were prescribed a THRZ of 60% to 70% of maximal heart rate (42% to 58% of VO_2 max). Soldiers completing three to four stages were prescribed a THRZ from 70% to 80% of maximal heart rate (58% to 70% of VO_2 max). Soldiers were expected to perform specific rhythmical activities (e.g., jogging, cycling, swimming, skating, etc) at the prescribed intensity for a duration of 15 to 60 min. Frequency of the soldier's aerobic exercise training was set at the discretion of the PE&R staff member.

In an extensive review of the interaction between intensity, frequency, and duration of exercise training on VO_2 max, Wenger and Bell (1986) demonstrated that optimal gains in VO_2 max were accomplished by training 4 times per week for 35 to 45 minutes at an intensity between 90 to 100% VO_2 max. Wenger and Bell (1986) emphasized intensity as "the key factor in producing improvements... [in VO_2 max]" (p. 353). As well, they stated that the minimum intensity necessary to evoke changes was 50% VO_2 max.

At present, there is limited research describing the effect military training has on the aerobic fitness level of soldiers. Gordon et al. (1986) examined the effect one year of military training had on VO_2 max. After a year in a military physical training program, post-training

VO_2 max values (53.1 ± 4.7 ml · kg^{-1} · min^{-1} and 3.69 ± 0.51 l · min^{-1}) did not significantly differ from pre-training values (53.0 ± 3.99 ml · kg^{-1} · min^{-1} and 3.62 ± 0.58 l · min^{-1}). Gordon et al.'s (1986) results, although not statistically significant, were as follows: soldiers with above average VO_2 max values exhibited decreased VO_2 max values; soldiers with average VO_2 max values maintained pre-training values; soldiers with below average VO_2 max values slightly increased in VO_2 max. Gordon et al. (1986) suggested that the lack of a significant increase in VO_2 max was due to inadequate physical conditioning programs, particularly aerobic training programs. In light of Gordon et al.'s (1986) and Wenger and Bell's (1986) research, the prescribed aerobic training intensities of the CF EXPRES program may been insufficient to produce the desired improvements in VO_2 max. This situation may have contributed to the fairly low VO_2 max values achieved by subjects in the present study.

Another possible explanation for the low VO_2 max values exhibited by the subjects of the present investigation may be related to the time of year in which the soldiers were tested. Seasonal variation affects many human physiological variables such as basal metabolism (Yoshimura et al., 1966), blood free-fatty-acid levels, and plasma glucagon (Kuroshima et al., 1979). Maximal oxygen consumption rates may also be affected by seasonal variation. Ingemann-Hansen and Halkjaer-Kristensen (1982) examined the effects that winter (February) and summer (July) had on a soldier's VO_2 max. Testing was performed in the city of Copenhagen (56° *N* latitude). VO_2 max values during the winter (mean = 42.5 ml · kg^{-1} · min^{-1} or 3.12 l · min^{-1}) were significantly ($p<0.05$) lower than VO_2 max values during the summer (46.9 ml · kg^{-1} · min^{-1} or 3.35 l · min^{-1}), even though training was the same in both cases. The soldiers in the present investigation were tested in the city of Calgary (~ 52° *N*

latitude) during the winter (January). The VO_2 max values for the soldiers in the present study were lower than that of combat arms personnel in Singh et al.'s (1991) study, who were tested in Edmonton (~ 55° *N* latitude) during the summer (June). This may partially explain the difference between Singh et al.'s (1991) findings and the results of the present study.

The effects of detraining during vacation may be another cause for the comparatively low VO_2 max values exhibited by the soldiers in the present study. Subjects in this investigation were tested for VO_2 max not long after returning from Christmas vacation. During vacation, physical activity patterns may have been inadequate to maintain or improve the aerobic fitness level of the soldiers. For instance, Saltin et al. (1968) demonstrated, using healthy male subjects, that after 20 days of bed rest, subjects' VO_2 max decreased by 27%. Following the bed rest period, subjects participated in a vigorous running program six days per week; in order for the subjects to regain pre-bed rest VO_2 max values, they had to train from 10 to 20 days. Although the soldiers in the present study were not bed-ridden during vacation, Saltin et al.'s (1968) investigation demonstrates how detraining may decrease VO_2 max, and also offers insight into the length of training time required to reverse detraining effects. In a more recent investigation of detraining, Coyle et al. (1984) demonstrated that within a two week period of low activity, VO_2 max for aerobically fit individuals decreased by as much as 6%.

Henriksson and Reitman (1977) demonstrated that detraining for as little as two weeks significantly reduced succinate dehydrogenase (SDH) and cytochrome oxidase, two enzymes commonly measured as markers of aerobic adaptation in muscle cells. Henriksson and Reitman's (1977) findings demonstrated that, after a two week detraining period, SDH and

cytochrome oxidase activity had declined to almost pretraining levels, whereas VO_2 max remained constant, indicating that enzyme activity was more sensitive to the effects of detraining than were cardiac or central adaptations (e.g., stroke volume). In addition, Henriksson and Reitman (1977) found that time to exhaustion, using a treadmill protocol, declined in a parallel fashion to decreasing levels of SDH and cytochrome oxidase activity. In the present study, the soldiers may have been fairly sedentary during vacation (approximately 2 weeks), which may have led to a reduction in aerobic enzyme activity, thus decreasing endurance ability. Since VO_2 max values, as estimated by the 20MSR, were dependent upon the duration of continuous running, a period of lower physical activity may have reduced the endurance capacity of the soldiers at the cellular level, producing lower estimated VO_2 max values.

Another possible cause for the fairly low relative VO_2 max values exhibited by the subjects in this investigation may be related to their high BMI values. High BMI values have been associated with decreased relative VO_2 max values. Jette et al. (1990b) reported BMI values for a cross-section of CF personnel to be 25-27 kg/m^2, which corresponded to a VO_2 max of 45.0 ± 6.4 ml $\cdot kg^{-1} \cdot min^{-1}$; Jette et al. (1990a) reported a mean VO_2 max of 50.2 ± 6.7 ml $\cdot kg^{-1} \cdot min^{-1}$ for subjects with BMI values of 23.8 ± 2.7 kg/m^2. The subjects in the present study had a mean BMI of 26.2 kg/m^2 and had a mean VO_2 max of 41.66 ± 5.12 ml $\cdot kg^{-1} \cdot min^{-1}$ The high BMI values exhibited by the subjects in the present study may partially explain the low VO_2 max values.

In the current study, the correlation coefficients (see Table 8) demonstrated that BMI values were significantly ($p<0.05$) and negatively related to relative VO_2 max ($r=-0.54$). In

addition, percent body fat was significantly ($p<0.05$) negatively related to relative VO_2 max ($r=-0.57$). These body composition measurements negatively influenced relative VO_2 max, indicating that higher BMI and percent body fat decreased relative VO_2 max. As previously discussed, excessive body fat may have led to increased aerobic demands, which may in part be due to the energy cost of carrying non-energy producing substances (i.e., adipose tissue) (Buskirk and Taylor, 1957).

Table 8.
Correlation Matrix of 20MSR performance, occupational tasks and fitness scores

	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
1. VO_2 ($ml \cdot kg^{-1} \cdot min^{-1}$)	--								
2. VO_2 ($l \cdot min^{-1}$)	.27*	--							
3. Trench Digging (s)	-.08	-.28*	--						
4. ISOC (s)	-.65*	-.10	.05	--					
5. Height (cm)	-.20	.45*	-.23	.19	--				
6. Weight (kg)	-.54*	.63*	-.19	.43*	.52*	--			
7. Skinfolds (mm)	-.57*	.14	.09	.46*	.23	.65*	--		
8. BMI (kg/m^2)	-.54*	.48*	-.07	.38*	.03	.86*	.62*	--	
9. Body fat (%)	-.57*	.17	.09	.45*	.24	.68*	.96*	.64*	--

* = $p \leq 0.05$

On the other hand, this investigation found that correlation coefficients between absolute VO_2 max and body weight ($r=0.63$), height ($r=0.45$), and BMI ($r=0.48$) were significantly ($p<0.05$) positively related. The correlations between these body dimension

characteristics and absolute VO_2 max indicate that the larger the soldier, the greater the absolute VO_2 max. Åstrand and Rodahl (1986) stated that absolute VO_2 max is proportional to body size; larger people tend to consume more oxygen because they have more tissue.

Low levels of aerobic fitness are commonly associated with health risk factors such as coronary heart disease (CHD), stroke, hypertension, and hyperlipidaemia (Brooks et al, 1996; Åstrand and Rodahl, 1986); in addition, there is evidence that suggests that low aerobic fitness increases one's susceptibility to injury (Knapik et al., 1993). Military organizations generally consider injury rates as a major problem in the military setting. The potential for injury in the military is high because of the vigorous nature of military training and operational duties. Knapik et al. (1993) reported that physical fitness affects the likelihood and potential for injuries, which are associated with substantial financial costs. Snoddy and Henderson (1994) estimated the cost of basic training to be $16,000 U.S. per soldier. In addition, Snoddy and Henderson (1994) demonstrated that lower levels of physical fitness prior to basic training were associated with higher injury rates during basic training. Knapik et al. (1993) also demonstrated that as aerobic fitness level decreased, the incidence of injury increased; they found that soldiers with the lowest aerobic fitness levels were 1.6 times more likely to experience an injury than those with the highest aerobic fitness level. In addition to issues of financial cost, injuries pose a threat to lost training time, thus reducing the efficiency of the training process.

Low aerobic fitness may also affect the ability of a soldier to perform certain military duties under physically and psychologically stressful situations (O'Connor et al., 1988). Kimick (1987) demonstrated that soldiers with high VO_2 max values (56.3 ± 7.2 ml $\cdot$ kg^{-1} $\cdot$

min^{-1} and 4.08 ± 0.58 l · min^{-1}) performed the ISOC 48% faster than subjects with low VO_2 max values (42.3 ± 1.7 ml · kg^{-1} · min^{-1} and 3.24 ± 0.46 l · min^{-1}). McGarvey (1996) demonstrated that performance of occupationally-related fitness tests (slit-trench digging and ammunition box lifting) were performed significantly faster by soldiers with higher VO_2 max values than by soldiers with lower VO_2 max values. Singh et al. (1991) demonstrated that the time required for trench digging and ammunition box lifting was significantly and negatively correlated with direct measures of both absolute and relative VO_2 max. The aforementioned literature supports the CF commanders' perception that performance of military tasks may be compromised as a result of poor cardiovascular fitness.

III. Slit-Trench Digging Performance

Mean slit-trench digging performance for the subjects in the present study was 259.84 ± 46.12 s (Table 9). The results of the present study were consistent with previous investigations of digging performance times. Singh et al. (1991) and Stevenson et al. (1992) reported slit-trench digging times of 262.0 ± 44.5 s and 252.8 ± 49.8 s, respectively.

Singh et al. (1991) and a panel of military experts recommended to the CF administration that 360 s be the maximum acceptable time for completion of the slit-trench digging test. During development of the minimum fitness standard for slit-trench digging, three (2.1%) of the subjects failed to meet the cut-off time of 360 s (Singh et al., 1991). In the present investigation, only one soldier (1.4%) failed to meet the minimum standard of 360 s. The similar failure rates and mean performance times in trench digging performance seem to indicate that the soldiers in the present investigation had similar physical abilities

to those of Singh et al.'s (1991) subjects.

Table 9.
Descriptive Statistics for Slit-Trench Digging Performance

Variable	n	mean	s.d.	minimum	maximum
Trench Digging (s)	74	259.84	46.12	149.0	386.0

Subjects in the present study and in the studies by Singh et al. (1991) and Stevenson et al. (1992) were CF personnel similar in age and height. However, subjects in the present study possessed higher percent body fat and lower VO_2 max values than the subjects in the other two investigations. Higher percentage of body fat and lower VO_2 max values have been equated with slower trench digging performance times. Yet, this study's subjects had similar digging times as those of Singh et al.'s (1991) and Stevenson et al.'s (1992) subjects.

Possible reasons for the similarities in trench digging performance times between the study groups may be the result of factors not studied in this investigation. Regression analysis by Singh et al. (1991) demonstrated that leg peak power and static trunk extension strength, in combination with VO_2 max, accounted for digging performance to a higher degree than VO_2 max alone. Stevenson et al. (1992) identified combined grip strength as a factor significantly related to digging performance. McGarvey (1996), investigating physiological differences between the top 27% and the bottom 27% performers in slit-trench digging, found that the top slit-trench digging performers had significantly superior ($p<0.05$) results in comparison to the bottom performers in terms of a number of physiological parameters including absolute and relative VO_2 max, leg power output, trunk flexion and extension strength, arm flexion strength, and arm power output. Thus, a number of physiological

components may have contributed to trench digging performance; many of these factors, which were not measured in this study, may account for the similarity in performance times amongst the research studies.

Another possible explanation why slit-trench digging performance times in the present study were similar to other investigations is that differences may have existed in terms of specificity of training. Slit-trench digging is an activity frequently performed by combat arms personnel; tasks that are performed on a regular basis tend to induce specific cardiorespiratory and muscular adaptations, which in turn produce proficiency in task performance (Sale, 1988). In a classic study, Holmer and Åstrand (1972) demonstrated the impact of specificity of training. During graded treadmill running, twin sisters exhibited the same VO_2 max values. However, during flume swimming, the sibling who regularly trained for competitive swimming had a 30% higher VO_2 max value.

Although VO_2 max values for Singh et al. (1991), Stevenson et al. (1992), and the present study were different, the subjects in the studies had similar trench digging performances. This may be related to the mode in which VO_2 max was determined. The present study determined VO_2 max by the 20MSR, Singh et al. (1991) used a graded treadmill test, and Stevenson et al. (1992) used the CAFT, all of which utilized a mode that stressed the leg musculature, while slit-trench digging is primarily an upper body activity. Thus, subjects may have had similar upper body characteristics yet dissimilar lower body characteristics. Accounting for the similarity in digging performance times between subjects in the present investigation and military personnel in previous investigations.

IV. Indoor Standardized Obstacle Course Performance (ISOC)

Mean ISOC performance time for subjects in the present study was 319.56 ± 38.36 s (Table 10). These times were similar to the ISOC performance times reported by Jette et al. (1990a) (317 ± 51 s). In order to produce a consistent ISOC performance time and maximize learning, Jette et al.'s (1990a) subjects performed the ISOC four times; the third trial produced the "best" ISOC performance time, which was similar to the performance time found in the present investigation. In order to maximize the learning effect, subjects in the present investigation practiced and performed the ISOC until they were thoroughly familiar with it, thereby ensuring that ISOC performance times during data collection were the subjects' best performance.

Table 10.
Descriptive Statistics of ISOC Performance

Variable	n	mean	s.d.	minimum	maximum
ISOC (s)	64	319.56	38.36	260.0	407.0

The similarity between the ISOC performance times in Jette et al.'s (1990a) study and in the present investigation is surprising in light of the body composition and aerobic fitness data previously described. Jette et al. (1990a) maintained that subjects with high VO_2 max values and low percentage body fat performed the ISOC faster than subjects with low VO_2 max values and a high percentage of body fat. The subjects in the present investigation had a lower VO_2 max (41.66 ± 5.12 ml · kg^{-1} · min^{-1} and 3.44 ± 0.046 l · min^{-1}) and a higher percentage of body fat (25.3 ± 4.76%) than the mean values reported in the study by Jette et al. (1990a) (50.5 ± 6.7 ml · kg^{-1} · min^{-1} and 3.7 ± 0.5 l · min^{-1}; 16.4% body fat). The

correlation coefficients in the present investigation demonstrated that body weight ($r=0.43$), percent body fat ($r=0.45$), and BMI ($r=0.38$) were all significantly ($p<0.05$) correlated with ISOC performance. The correlations indicated that increases in these anthropometric measures increased ISOC performance time. Yet, ISOC performance times in the present investigation were similar to those in Jette et al.'s (1990a) study.

A possible explanation for this similarity in ISOC performances may be related to protocol differences between the present and Jette et al.'s studies. Jette. et al.'s (1990a) subjects carried a rifle (4.5 kg) and wore a helmet (0.5 kg) while performing the ISOC. When the extra weight of the helmet and rifle (5.0 kg) are added to the soldiers' mean body weight (73.8 kg), the total mean weight of the soldiers (78.8 kg) in Jette et al.'s (1990a) study is somewhat closer to the mean body weight of the subjects in the present investigation (83.5 kg). However, the excess weight carried by Jette et al.'s (1990) subjects does not account for all of the difference in performance. The awkwardness of the rifle may have been an even greater impediment to performing the ISOC. The soldiers in Jette et al.'s (1990a) study had to sling and unsling the gun from their shoulder throughout the course, which may have impaired the subject's ability to move quickly during the ISOC. Although Jette et al.'s (1990a) subjects had higher VO_2 max values and lower percentage body fat than the subjects in the present investigation, the combined effects of both the weight and the awkwardness of the rifle may have caused Jette et al.'s (1990a) subjects to perform the ISOC in about the same amount of time as the subjects in the present investigation.

Another possible reason why subjects in this investigation had similar ISOC performance times as Jette et al.'s (1990a) subjects may be related to specificity of training.

The ISOC was composed of common military tasks routinely performed by CF personnel. Soldiers in the present investigation and in Jette et al.'s (1990a) study may have developed the specific musculature and energy systems required to perform the ISOC at a similar performance level, just as specific adaptations may account in part for performance similarities in trench digging.

Finally, Jette et al. (1990a) demonstrated that a variety of physiological factors were significantly related to ISOC performance, including VO_2 max, anaerobic leg power, muscular strength, and sum of skinfolds. Stepwise regression analysis demonstrated that VO_2 max, strength index, anaerobic power, and skinfolds accounted for 81% of ISOC performance. A combination of the above physiological factors, which were not examined in the present investigation, may account for the similarity in ISOC performance times in the present study and in Jette et al.'s (1990a) study.

B. INFERENTIAL STATISTICS

The CF regards VO_2 max as an important measure of a soldier's ability to perform his or her duties. The determination of VO_2 max by direct measures of gas exchange has proven to be the most accurate and reliable method (Thoden, 1992). However, these techniques are time consuming and involve the use of expensive equipment and highly skilled technicians. The CF requires a VO_2 max test that is easy to administer and inexpensive, yet reliable and accurate. In addition, values obtained from the VO_2 max test should be related to measurements of performance in military activities such as slit-trench digging and the ISOC. Singh et al. (1991) demonstrated that slit-trench digging performance was significantly

($p<0.05$) correlated with direct measures of absolute ($r=-0.48$) and relative ($r=-0.35$) VO_2 max. Jette et al. (1990a) demonstrated that ISOC performance had a significant ($p<0.05$) correlation with direct measures of absolute ($r=-0.62$) and relative ($r=-0.73$) VO_2 max.

Since the CF requires VO_2 max tests that are less expensive than direct measures of VO_2 max, the CF has examined the use of the Canadian Aerobic Fitness Test (CAFT), a predictive test of VO_2 max. It was also necessary to determine if the CAFT complied with the Canadian Human Rights legislation in regard to bona fide occupational guidelines. Stevenson et al. (1992) examined the relationship between the CAFT and slit-trench digging, attempting to determine whether a reliable (significant) relationship existed between the two. Stevenson et al. (1992) defined a reliable relationship as the occurrence of a significant relationship between the general fitness variables (i.e., CAFT) and military tasks (i.e., slit-trench digging). The methodology Stevenson et al. (1992) used involved the statistical analysis of the performance results of the CAFT and the slit-trench digging tasks. The performance results were then analyzed using Pearson Product Moment Correlation and regression analysis. Stevenson et al. (1992) did not find a significant correlation between performance on the CAFT and in trench digging ($r=-0.26$), nor did they find a significant relationship through the use of regression analysis; therefore, based on Stevenson et al.'s (1992) criteria, the CAFT failed to meet the requirements, in regard to bona fide occupational guidelines, set forth by Canadian Human Rights legislation. As a result of Stevenson et al.'s (1992) study, the CF rejected the CAFT as a suitable aerobic power test for the CF. The CF elected to examine the 20MSR, another predictive test of VO_2 max that was cost effective, easy to administer, reliable and valid. However, there had been no examination of the

20MSR's relationship to occupationally related tests.

I. Relationship between 20 Meter Shuttle Run and Slit-trench Digging

In the present investigation, absolute VO_2 max, as determined by the 20MSR, was significantly ($p<0.05$) correlated with slit-trench digging performance ($r=-0.28$). Singh et al.'s (1991) study, the only other examination of the relationship between direct measures of absolute VO_2 max and slit-trench digging performance, also demonstrated a significant correlation ($r=-0.48$). The correlation coefficient from both Singh et al.'s (1991) study and the present investigation indicate that as absolute VO_2 max increased, slit-trench digging performance time decreased.

On the other hand, the present investigation showed a non-significant correlation coefficient ($r=-0.08$) between relative VO_2 max, as determined by the 20MSR, and slit-trench digging performance. In rejecting the CAFT as a suitable military VO_2 max test, Stevenson et al. (1992) also reported a non-significant correlation ($r=-0.26$) between relative VO_2 max and slit-trench digging performance. However, Singh et al. (1991) reported a significant correlation ($r=-0.35$) between direct measurement of VO_2 max and slit-trench digging performance.

In the present investigation, regression analysis revealed that absolute VO_2 max was the only variable significantly ($p<0.05$) related to slit-trench digging performance (Table 11). Absolute VO_2 max accounted for only 8% of slit-trench digging performance, although this percentage is still significant ($p<0.05$). Singh et al. (1991), using multiple regression analysis, demonstrated that absolute VO_2 max, determined by direct measures, in combination with

measures of leg extension strength and trapezius lift, accounted for 36% of the variance in slit-trench digging performance.

Table 11.
Linear Regression Analysis for the Prediction of Slit-trench Digging and ISOC performances from 20MSR performance

Model[1]	*Variable*	*B values*	*Intercept*	*Significance*	R^2
Trench digging	VO_2 max abs	-27.1	351.3	0.018	0.08
ISOC	VO_2 max rel	-5.16	531.1	0.0001	0.42

[1] Model refers to the dependent variable in the regression equation predicted by VO_2 max variables derived from 20MSR

II. Relationship between 20 Meter Shuttle Run and Indoor Standardized Obstacle Course

In the present investigation, relative VO_2 max, as determined by the 20MSR, was significantly ($p<0.05$) correlated with ISOC performance ($r=-0.65$) (Table 8). Jette et al.'s (1990a) study, the only examination of the relationship between direct measures of relative VO_2 max and ISOC performance, also demonstrated a significant correlation ($r=-0.73$). The correlation coefficient from both Jette et al.'s (1990a) study and the present investigation indicated that as relative VO_2 max increased, ISOC performance time decreased.

In the present investigation, absolute VO_2 max, as determined by the 20MSR, was not significantly correlated with ISOC performance times ($r=-0.10$). However, Jette et al. (1990a) demonstrated that directly measured absolute VO_2 max was significantly correlated with ISOC performance ($r=-0.62$). The correlation coefficient reported by Jette et al. (1990a)

indicated that as absolute VO_2 max increased, ISOC performance time decreased.

Regression analysis in the present investigation revealed that relative VO_2 max was significantly ($p<0.05$) related to ISOC performance (Table 11). Relative VO_2 max accounted for 42% of ISOC performance. Jette et al. (1990a), using a multiple regression analysis, demonstrated that relative VO_2 max, determined by direct measures, accounted for 54% of ISOC performance time.

In the current study, possible explanations why slit-trench digging performance was significantly related to absolute VO_2 max but not to relative VO_2 max may be related to the activity pattern involved in the tasks examined. In addition, activity patterns may account for the significant relationship between relative VO_2 max and ISOC performance and the non-significant relationship between absolute VO_2 max and ISOC performance.

Shephard (1991) stated that the choice whether to measure either absolute or relative VO_2 max logically depends on the nature of the task. "If a large part of the work to be performed is external to the individual, a high absolute value is needed, but if much of the energy cost is attributable to a displacement of body mass, then the relative score is the appropriate value to consider" (p. 98). Åstrand and Rodahl (1986) stated that in work and exercise situations in which the body is lifted (as in walking, running, and climbing), the oxygen uptake in relation to body weight (relative) is more relevant than the liter $\cdot$ min^{-1} figure. Thoden (1991) provided furthered support for this argument by stating that when aerobic power is expressed in terms of oxygen, it is usually reported as an absolute volume per minute ($l \cdot min^{-1}$) for sports such as rowing, in which total work output is important, and as a volume per minute relative to body weight ($ml \cdot kg^{-1} \cdot min^{-1}$) in activities such as cross-

country running, in which body weight is supported during the performance (p. 108).

Slit-trench digging involved the removal of an absolute load of gravel (0.5 m^3), as quickly as possible, while maintaining a relatively stationary position, from one side of the trench simulator to the other; the task required predominantly upper body work, as in canoeing. Tesch et al. (1976) demonstrated that it is more meaningful to express a canoeist's VO_2 max in terms of absolute ($l \cdot min^{-1}$) measures, as opposed to relative ($ml \cdot kg^{-1} \cdot min^{-1}$) terms, because a canoeist's body weight is supported by the canoe during the activity and changes in body weight do not significantly affect performance. Similarly, absolute measures of VO_2 max may be more appropriate for slit-trench digging because the body is supported and relatively stationary.

As previously discussed, Åstrand and Rodahl (1986) stated that for activities that require the body to be lifted (as in walking, running, and climbing), the expression of VO_2 max is more relevant in terms of relative ($ml \cdot kg^{-1} \cdot min^{-1}$) than absolute ($l \cdot min^{-1}$) values. The ISOC required subjects to run, climb, and crawl throughout the course; at times, the subjects had to carry loads, thus increasing the energy requirements of the tasks (Evans et al., 1983). Finally, in an investigation by Rohdes and Farenholtz (1992), they demonstrated that relative VO_2 max was significantly related to obstacle performance time.

C. SUMMARY

Stevenson et al. (1992) stated that in order to establish a reliable relationship between general fitness variables and occupationally-related fitness tests, a significant relationship between the two would have to be shown, using Pearson Product Moment Correlation

coefficients and regression analysis. This investigation attempted to determine whether a reliable relationship existed between the 20MSR and CF occupationally-related tasks, specifically, the ISOC and trench digging tasks. Simple correlation and linear regression analysis indicated a significant relationship between the 20MSR and occupationally-related fitness tests (Table 9 and 11). However, the relationship between the 20MSR and these tests was dependent upon the form of expression of VO_2 max. Relative VO_2 max was particularly important for the determination of ISOC performance, whereas absolute VO_2 max was correspondingly important for slit-trench digging performance. The low to moderate correlation coefficients between 20MSR scores and task performance, in addition to regression analysis, suggested that factors not examined in this study (e.g., anaerobic power, muscular strength, and muscular endurance) may explain the unaccounted variance in ISOC and digging performances. Singh et al. (1991) and Jette et al. (1990a) reported that a combination of physiological factors, including muscular strength, anaerobic power, and muscular endurance, accounted for the variation in digging and ISOC performance.

The CF requires an aerobic fitness test that is valid, objective, cost effective, and easy to administer. For many years, the Canadian Aerobic Fitness Test was the official aerobic fitness test for the CF, but it was costly, difficult to administer, and did not show significant relationships with performance on selected military tasks. Thus, the CAFT is being phased out of the CF testing battery. The CF Directorate of Physical Education and Recreation is currently examining the 20MSR's practicality and whether it is related to occupational military activities. In order for the 20MSR to meet the bona fide occupational guidelines, it is necessary to demonstrate a significant relationship between performance on the 20MSR

and on occupationally-related tasks (Shephard, 1990). Previous research has demonstrated that direct measures of VO_2 max are related to slit-trench digging and the ISOC performances (Singh et al., 1991; Jette et al., 1990a). Although significant relationships were found between 20MSR scores and performance in the ISOC, and trench digging, the relationships were not of the same magnitude as between direct measures of VO_2 max and selected military tasks. The current investigation provides evidence that supports the 20MSR's ability to meet the bona fide occupational guidelines. However, in the sense that only a select group of CF personnel were studied, this investigation does not provide conclusive evidence.

CHAPTER V

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

A. SUMMARY

Soldiering has been described as one of the most demanding non-civilian occupations (Daniels, 1984; Jette et al., 1990a). Due to the intense physical requirements of military duty, the CF has opted to test soldiers regularly to determine their physical ability to perform in combat situations. Aerobic fitness is one component that is important to the performance of CF activities (Daniels et al., 1984). In order to test aerobic fitness, the CF has introduced the 20MSR, a valid, reliable, easy to administer, predictive test of VO_2 max (Leger and Gadoury, 1988; Montgomery et al., 1992). However, before full implementation, the 20MSR must meet the bona fide occupational guidelines set forth by Canadian Human Rights legislation. To meet the guidelines, it must be demonstrated that there is a reliable relationship between scores on the 20MSR and performance of occupationally-related CF activities. This study examined the relationship between performances on the 20MSR and on two occupationally-related CF fitness tests, the slit-trench digging test and the Indoor Standardized Obstacle Course (ISOC).

Seventy-five male infantry soldiers (26.69 ± 4.53 years) from Canadian Forces Base Calgary (Alberta) participated in this investigation. The sample was composed of members from various military occupational groups including the service battalion (mechanics), Princess Patricia's Canadian Light Infantry (infantry), the signal squadron (communications), and the Lord Strathcona Horse division (armoured vehicle personnel). Prior to data

collection, all subjects were thoroughly familiarized with each of the testing protocols. Over a two day period, each individual soldier performed the 20MSR, slit-trench digging, and ISOC.

Pearson Product Moment Correlations and simple linear regression equations were computed to determine the relationships between selected variables. Results demonstrated a significant ($p<0.05$) relationship between performance on the 20MSR and performance on trench digging ($r=-0.28$) and ISOC ($r=-0.65$). Regression analysis demonstrated that VO_2 max significantly contributed to performance levels of occupationally-related fitness tests. However, other physiological factors not examined in this investigation may also be important for the performance of the occupationally-related tests examined.

B. CONCLUSIONS

Within the limits of this study, the following conclusions were drawn:

1. There was a significant ($p< 0.05$) reliable relationship between absolute VO_2 max, estimated by the 20MSR, and slit-trench digging performance.
2. There was a significant ($p< 0.05$) reliable relationship between relative VO_2 max, estimated by the 20MSR, and ISOC performance.

C. RECOMMENDATIONS

The following recommendations are made:

1. Given that the present investigation was limited to male CF personnel from the combat arms division, a similar study using a larger cross-section of CF personnel,

including females, from different occupational categories should be investigated.

2. The Canadian Forces need to examine current and possible alternative aerobic training programs, in order to promote adequate development of the aerobic fitness level of CF personnel.

3. The Canadian Forces should examine the health status and nutritional patterns of its soldiers. The relatively high body fat levels of the subjects in this study may be cause for concern.

4. A reliable relationship was demonstrated between performance on the 20MSR and on selected military activities, in accordance with the requirements of Canadian Human Rights Legislation. Thus, providing justification for the use of the 20MSR as a means of VO_2 max prediction for male soldiers between the ages of 20 and 38 years.

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APPENDIX A. ADMINISTRATIVE FORMS

1. Health Appraisal Questionnaire Form.
2. Informed Consent Form.
3. Testing Advisory

A1. HEALTH APPRAISAL QUESTIONNAIRE
(CF EXPRESS, 1989)

This questionnaire is a screening device to identify those members for whom physical activity might be inappropriate at the present time.

To the best of your knowledge:

	Yes	*No*
1. Do you have a restricted medical category which may prevent you from being evaluated or participating in a progressive training program?		
2. Do you have any acute or recurring problems with your back, shoulders, hips, knees or ankles which may prevent you from being evaluated or participating in a progressive training program?		
3. Do you suffer from such things as: High blood pressure, heart disease, asthma, bronchitis, emphysema, diabetes, epilepsy, arthritis or cancer or from previous injuries that might limit your ability to do a exercise test.?		
4. In addition to the above is there anything which you feel should be discussed with a medical officer prior to assessment?		
5. Are you taking medication (prescribed or otherwise) which may affect your ability to undertake a physical evaluation?		

6. How are you feeling today?

Excellent *Good* *Physically tired* *Mentally tired* *Don't feel good at all*

Other (please specify)

Date: _____ NAME: _____

A2. INFORMED CONSENT FORM FOR PHYSICAL FITNESS TRAINING STUDY

I, _____ authorize Dr. M. Singh and Randy Dreger of the University of Alberta to administer fitness tests and conduct fitness training.

Detailed instructions of tests and training program will be given to me prior to the start of the study. Laboratory tests will consist of: aerobic power, anaerobic power, muscular strength, muscular endurance, and body composition. Based on the results of these tests, I will be assigned to one of the four study groups.

For assessing aerobic power, I will perform shuttle runs which involves running back and forth on a 20 meter course within a specified time. Throughout this period my heart rate will be monitored using a sport tester heart rate monitoring device.

Anaerobic tests will include pedalling/cranking leg and arm ergometers at maximal effort for 30 second periods in order to determine lower and upper body anaerobic muscle power. A sport tester heart rate monitor will also be worn to assess warm-up and recovery phases during these tests. I am aware that I will be giving blood samples for assessment of the effects of testing and training.

The muscular strength and endurance capacity test battery consists of:

1. The isometric strength test battery consisting of handgrip, arm flexion at elbow angle of 105 degrees, trunk flexion and extension at hip angle of 160 degrees. For each test, before attempting maximal contractions, I will be required to perform a warm-up contraction at an intensity of 50-60 percent of the maximal voluntary effort. After a warm-up contraction for five seconds, I will perform two maximal voluntary contractions. Each contraction will be five seconds in duration. The maximal force generated during either contraction will be recorded. A rest period of three minutes will be given between each contraction.

2. The isokinetic-concentric strength test battery consists of arm flexion, leg extension, trapezius lift (similar to the movement of lifting an ammunition box from waist to shoulder height), bench press, trunk flexion and extension in hip angle range of 170-150 degrees, and knee extension and flexion. The first four tests are to be conducted at a cable velocity of 13 cm/s (Okoro, 1987). The trunk extension and flexion tests will be conducted at a cable velocity of 6.5 cm/s (Ashton, 1973). Empirical observations of various task performance indicates that these trunk movements tend to occur at slower velocities than that of the peripheral joints such as those of legs and arms. The knee extension and flexion tests will be conducted at an angular velocity of 180 degrees per second. This speed is specific to the knee movements seen in weight load marching. For each of these tests a warm-up set of six repetitions at a submaximal intensity will be conducted at 50-60 percent of my maximal voluntary effort. Following the warm-up

contraction, I will perform two sets of two maximal voluntary contractions.

3. The isometric endurance capacity test battery consist of handgrip, and arm flexion endurance. These tests will be conducted at loads similar to those encountered in the performance of common army tasks.

4. Dynamic endurance capacity test will consist of the trapezius lift. This test will be conducted utilizing a free-weight dynamometer with loads encountered in common army tasks (20 kg.).

5. The body composition determination will involve skinfolds and Bioelectrical Impedance methods.

Field tests include performances of casualty evacuation for 100 m, digging at a maximum effort, ammunition box lift, and weight load marching for up to 13 km. During the performance of all of these tests my heart rate will be recorded using a sport tester heart rate monitor.

For the casualty evacuation task, I will be required to evacuate an individual of my approximate body weight for a distance of 100 meters at maximum speed.

For maximum effort digging task, I will be required to dig gravel from a slit trench simulator. The quantity of the gravel will be 0.5 cubic meter. This quantity represents the approximate volume of a one slit trench which is 1.8 m x 0.6 m x 0.45 m in dimensions.

For the weight load march task, I will be required to march 13 km at a pace of 88.9 meters per minute with full fighting order (24.5 kg). This pace is equivalent to a marching speed of 5.33 km/h.

For the ammunition box lift task, I will be required to lift 48 boxes (one box at a time) from the floor and place them at a height of 1.3 meters (height of a truck bed). Each box weighs 20.9 kg.

For the 19 item Indoor Standardized Obstacle Course (ISOC) I will be involved in running, crawling, scaling, pulling, lifting, carrying and pushing events arranged in a sequential order. The purpose of this test is to assess the fitness of soldiers by execution of tasks similar to those which are encountered in combat type conditions.

If I have any question or concerns in regard to performance of any of the tests, I will check with one of the Research Team Members.

I acknowledge that the testing procedures have been fully explained to me and every effort will be made to conduct all the tasks in such a way as to minimize discomfort and risk. However, I understand that just as with other types of physical testing there are potential

risks. These include episodes of transient lightheadedness, fainting, chest discomfort, leg cramps, nausea and extremely rarely, heart attacks. If, for any reason, I experience personal discomfort (chest pain, shortness of breath, nausea, etc.), or threats to my safety, I may terminate the test(s) and/or my participation in the training program without any explanation or prejudice.

I know that during the test and training procedures, I am on military duty and am entitled to all rights and considerations pertaining thereto.

DATE: _____ SUBJECT: _____

(Signature)

WITNESS: _____

A3. TESTING ADVISORY

To: All Participants

Prior to testing sessions, please note the following:

1. Do not smoke within four hours to start of testing.
2. Do not drink coffee or tea (or other beverages containing Caffeine) within four hours prior to your testing session.
3. Do not eat at least two hours prior to a test session. If you can not avoid eating, eat lightly.
4. Do not consume any alcoholic beverages at least 24 hr prior to a test session.
5. Do not exercise strenuously within 24 h prior to your test session.
6. Do be on time for your test session, if possible, be early.
7. If you have any question(s) talk to one of the test coordinators.

APPENDIX B. TABLE OF PREDICTION

1. Prediction of VO_2 max from the 20 Meter Shuttle Run Test

B1. Prediction Table of VO_2 max from the 20 Meter Shuttle Run Test

Stage (min)	Max Speed ($km \cdot h^{-1}$)	Predicted VO_2 max ($ml \cdot kg^{-1} \cdot min^{-1}$)
1	8.5	23.6*
2	9.0	26.6
3	9.5	29.6
4	10.0	32.6
5	10.5	35.6
6	11.0	38.6
7	11.5	41.6
8	12.0	44.6
9	12.5	47.6
10	13.0	50.6
11	13.5	53.6
12	14.0	56.6
13	14.5	59.6
14	15.0	62.6
15	15.5	65.6*
16	16.0	68.6*
17	16.5	71.6*
18	17.0	74.6*
19	17.5	77.6*
20	18.0	80.6*

Age = 18.0 - 18.9 years old and so on...

Speed, $km \cdot h^{-1} = 8 \pm 0.5$ Stage, number or minute

VO_2 max ($ml \cdot kg^{-1} \cdot min^{-1}$) = 31.025 + 3.238 Speed ($km \cdot h^{-1}$) - 3.248 Age (year) + 0.1536 Speed x Age

Values with an * are extrapolated values beyond the $\pm$ 2 s experimental range of data

APPENDIX C. SCHEDULE OF TESTING EVENTS

1. Schedule of testing events during the morning session

2. Schedule of testing events during the afternoon session

C1. Schedule of Testing Events in the Morning Session

STATION	TESTS	WORK TIME	REST TIME	PERSONNEL
A	Knee extension & flexion	10 min.	5 min.	2
B	Casualty evacuation	5 min.	5 min.	2
C	Maximal effort digging	5 min.	15 min.	2
D	Trunk flexion-isom., isoton	10 min.	0 min.	2
E	Arm flexion & Bench press	10 min.	0 min.	2
F	Ammunition box carry	10 min.	15 min.	2
G	Well's sit & reach	5 min.	0 min.	1
H	Body comp. & Hand grip	10 min.	5 min.	1
Total		65 min.	45 min.	14

Note: 20 meter shuttle run was tested after all of the subjects had completed the other tests.

The following is the way in which the test circuit was designed - B - C - G - D - F - A - H - E

C2. Schedule of Testing Events in the Afternoon Session

STATION	TESTS	WORK TIME	REST TIME	PERSONNEL
A_2	Leg ext., trunk ext.-isom. isok.	20 min.	10 min.	2
B_2	Lower body wingate	10 min.	30 min.	3
C_2	Arm flexion endurance	5 min.	5 min.	1
D_2	Trapezius endurance	10 min.	10 min.	1
E_2	Upper body wingate	10 min.	10 min.	3
Totals		55 min.	65 min.	10

Note: The ISOC test was run after all of the subjects had completed the test battery.
Note: The weight load march was performed on separate days.

The following is the way in which the test circuit was designed - D_2 - E_2 - A_2 - B_2 - C_2